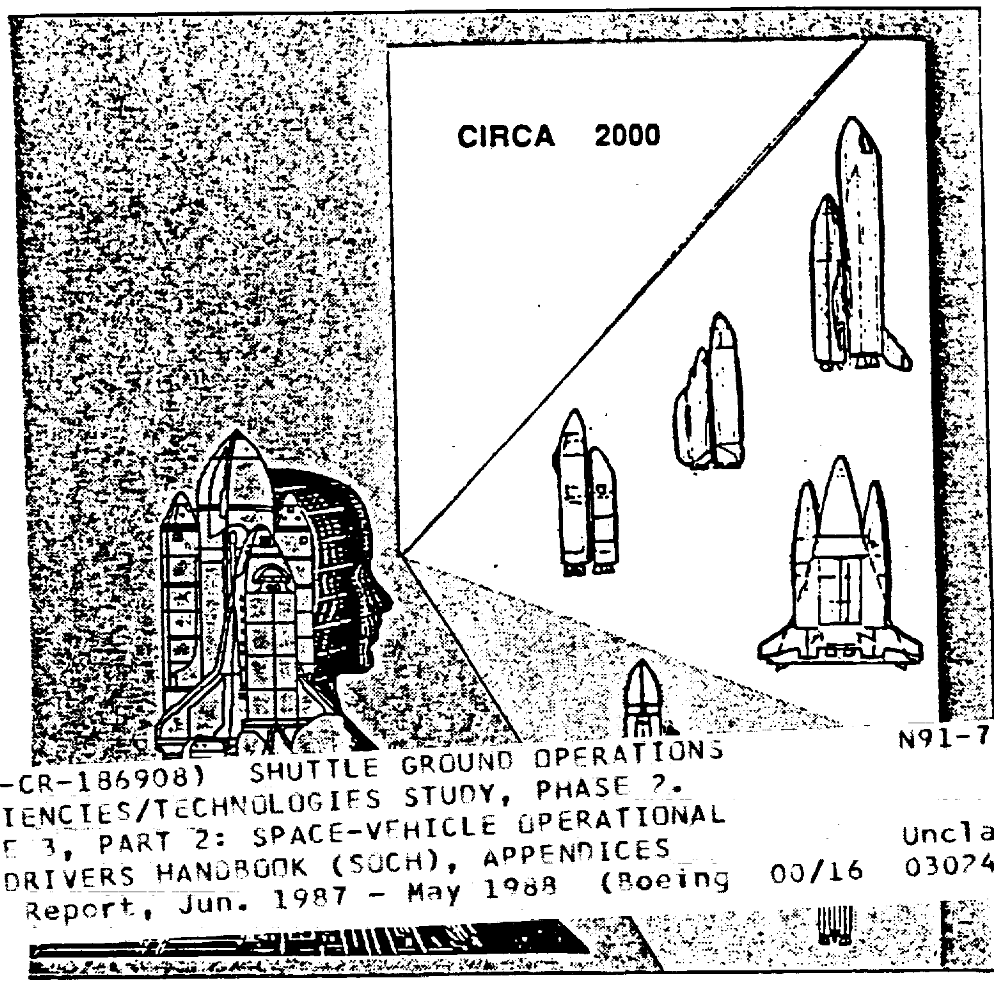
Shuttle Ground Operations Efficiencies/Technologies Study

BOEING

AEROSPACE OPERATIONS



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(NASA-CR-186908) SHUTTLE GROUND OPERATIONS
EFFICIENCIES/TECHNOLOGIES STUDY, PHASE 2.
VOLUME 3, PART 2: SPACE-VEHICLE OPERATIONAL
COST DRIVERS HANDBOOK (SOCH), APPENDICES
Final Report, Jun. 1987 - May 1988 (Boeing 00/16

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FINAL REPORT PHASE 2
Volume 3 (Part 2) of 6

SPACE-VEHICLE OPERATIONAL COST-DRIVERS HANDBOOK SOCH
(APPENDICES)

PREPARED BY:
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KENNEDY SPACE CENTER
NAS10-11344
May 5, 1988

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SHUTTLE GROUND OPERATIONS EFFICIENCIES / TECHNOLOGIES STUDY

PHASE 2 FINAL REPORT

STUDY REPORT

Volume 1 EXECUTIVE SUMMARY

The Executive Summary provides an overview of major elements of the Study. It summarizes the Study analytic efforts, the documentation developed, and reviews the recommendations resulting from the analyses conducted during Phase 2 of the Study.

Volume 2 PHASE 2 FINAL ORAL PRESENTATION

The Final Presentation Material volume contains the charts used in the Final Oral Presentations for Phase 2, at KSC on April 6, 1988. A brief, overall review of the Study accomplishments is provided. An indepth review of the documentation developed during the last quarter of Phase 2 of the Study is presented. How that information was used in this Study is explained in greater detail in Vols. 3 and 4. An initial look at the topics planned for the upcoming Workshops for Government/Industry is presented along with a cursory look at the results expected from those Workshops.

Volume 3 SPACE-VEHICLE OPERATIONAL COST DRIVERS HANDBOOK (SOCH)

The Space-vehicle Operational Cost drivers Handbook (SOCH) was assembled early in Phase 2 of the Study as one of the fundamental tools to be used during the rest of the Phase. The document is made up of two parts -- packaged separately because of their size.

Part 1 Presents, in checklist format, the lessons learned from STS and other programs. The checklist items were compiled so that the information would be easily usable for a number of different analytical objectives, and then grouped by disciplines or gross organizational, and/or functional responsibilities. Content of the checklists range from 27 management; 11 system engineering; 8 technology; and 19 design topics -- with a total of 793 individual checklist items. Use of this Handbook to identify and reduce Cost Drivers is recommended for designers, Project and Program managers, HQ Staff, and Congressional Staffs.

Part 2 Contains a compilation of related reference information about a wide variety of subjects including ULCE, Deming, Design/Build Team concepts as well as current and previous space launch vehicle programs. Information has been accumulated from programs that range from, Saturn/Apollo, Delta, Titan, and STS to NASP and Energia.

Volume 4 SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA (SLSOC)

The SLSOC document was developed from the generic Circa 2000 System document, Vol. 6; is similar in content; and also indicates the manpower effect of the elimination of many STS-type cost drivers. The primary difference between the two documents is the elimination of all generic Circa 2000 requirements (and support) for manned-flight considerations for the ALS vehicle. The data content of the two documents, while similar in nature, was reorganized and renumbered for SLSOC so that it could be used as the basis for various panels and subpanels in an ALS Workshop.

PHASE 2 STUDY REPORT (Cont'd)

Historical data is the basis for the conclusion that incremental improvements of technology and methods cannot significantly improve LCC (by an order-of-magnitude) without major surgery. A system enabling the development of a radically simplified operational concept, reflected in SLSOC, was included so that proposed designs (and operations) could be compared to systems providing for simplicity -- rather than the current STS complexity.

The identified operational cost drivers from STS plus other historical data were used as background reference information in the development of each example concept designed to eliminate cost drivers. These example concepts, when integrated, would support an order-of-magnitude cost reduction in current (STS), exorbitant Life Cycle Costs (LCC). Individual operational requisites were developed for each element in the associated management systems, integration engineering, vehicle systems, and supporting facilities. These have associated rationale, sample concepts, identification of technology developments needed, and technology references to abstracts. The technology abstracts are provided in a separate volume, Vol. 5.

Technology changes almost daily, thus past trade studies may no longer be valid. In addition, old "trades" often used inaccurate estimates of "real" operational costs. Vehicle designs are compromises and have been performance oriented with operations methods/techniques based on those designs. It is the intent of our example concepts in the SLSOC to stimulate design teams to improve or replace conventional design approaches. Obviously, it is up to the responsible program design teams to provide design solutions to resolve operational cost drivers.

Volume 5 TECHNOLOGY REFERENCES

This document provides a repository for the Technology References for the SLSOC and the CIRCA 2000 System documents. The technology references, mostly from NASA RECON, are supplied to the reader to facilitate analysis on either the SLSOC or the CIRCA 2000 System documents. Some data references were also obtained via DIALOG. If more technical information is desired by an analyst, he must obtain the additional documentaiton thru his library or from some other appropriate source. The XTKB (EXpanded Technology Knowledge Base) provided a user-friendly tool for our analyses in identifying and obtaining the computerized database reference information contained in this document. Thousands of abstracts were screened to obtain the 300 plus citations pertinent to SLSOC in this Volume.

Volume 6 CIRCA 2000 SYSTEM OPERATIONAL REQUIREMENTS

The Circa 2000 System Operations Requirements were developed using STS as a working data source. We identified generic operations cost drivers resulting from performance-oriented vehicle design compromises and the operations methods/techniques based on those designs. Those Cost Drivers include high-cost, hazardous, time & manpower-consuming problem areas involving vehicles, facilities, test & checkout, and management / system engineering. Operational requisites containing rationale, example concepts, identification of technology developments needed, and identification of technology references using available abstracts were developed for each Cost Driver identified. Elimination of cost drivers significantly reduces recurring costs for prelaunch processing and launch operations of space vehicles.

NOTE: Volumes 1,3,4 and 5 are being widely distributed. Volume 2 is a copy of presentation material already distributed and Volume 6 will be distributed only on request. Copies of the full report will be placed in libraries at NASA HQ., JSC, KSC, MSFC and NASA RECON. Individual volume copies may be obtained by forwarding a request to W. J. Dickinson, KSC PT-FPO, (407) 867-2780.

Space-Vehicle Operational Cost-Drivers Handbook (SOCH)
APPENDICES

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6.0 INTRODUCTION

The appendices to the Space-Vehicle Operational Cost-Driver Handbook (SOCH) are included to: (1) provide references for some of the topics in the basic SOCH document and (2) provide users with a selected survey of historical, current and future program background data in an easily referenced format.

The types of data include pad configuration for Apollo and STS; comparative vehicle sizes, weights, and thrust; mission results; future manifests for STS and Arriane, and foreign vehicle statistics/configurations/planning. Also included is the complete file on topics referenced in the SOCH such as Deming's Management Principles, Unified Life Cycle Engineering and recommended Space Transportation Architecture Study configurations. All of these provide background for comparisons of space vehicle operations in the past, present and future.

The U.S. and foreign commercial publication data selected for use in preparing the Handbook are reproduced here with permission of the respective publishers. Also included are NASA and NASA contractor briefing documents, and fact sheets.

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6.1 UNIFIED LIFE CYCLE ENGINEERING (ULCE)

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IMPLEMENTATION PLAN

FOR

UNIFIED LIFE CYCLE ENGINEERING (ULCE)

February 1987

FOREWORD

This implementation plan defines the organizational structure and goals to be addressed in attaining the ULCE objective of changing the design environment as was defined in Project FORECAST II. It describes the expected results, the approach to be taken in implementing the ULCE objectives, the participants, and the schedules.

The plan also defines and identifies the set of Core Projects with which to accomplish these objectives, as well as those ongoing Related Programs that are essential to the ULCE environment.

The planning details contained herein are dynamic, and will become progressively more specific as details are developed, new research added, and/or changes are made. These will be contained in periodic revisions to the plan.

EXECUTIVE SUMMARY

A. DEFINITION

Unified Life Cycle Engineering (ULCE) is a design engineering environment in which computer-aided design technology is used to continually assess and improve the quality of a product during the active design phases as well as throughout its entire life cycle by integrating and optimizing design attributes for producibility and supportability with design attributes for performance, operability, cost, and schedule.

B. OBJECTIVE

The objective of the Unified Life Cycle Engineering (ULCE) Program is to develop, demonstrate, and transfer to application the techniques and technologies needed to provide advantageous, computerized integration of the procedures dealing with designing for producibility and designing for supportability with those dealing with designing for performance, cost, and schedule. Integration will consider the two-way data flow, data structure, and compliance with interface standards for design information flowing within the ULCE process, as well as to and from other users of that information (e.g., Computer Aided Logistic Support [CALS]). The program planning will take maximum advantage of related Government and Industry initiatives and products and identify for development those ULCE essential procedures that are not yet available--for example, supportability models and design decision aids.

C. EXPECTED RESULTS

The development and demonstration tasks planned to be performed will prove that the ULCE environment will assist design engineers to produce designs that are right the first time, thus serving both the needs of the military and private enterprise.

The planned ULCE programs will provide design aiding tools for use by both industry for designing and the Government for design checking/optimizing, design specification preparation, proposal evaluation, reprocurement, and in-house manufacturing. These programs will be deliberately designed for modularity and availability to permit cost effective application by small contractors as well as large ones. This will result in considerable improvement in weapon system acquisition, development time and cost. It will also provide significant increase in readiness, and warfighting capability because the total design and manufacturing community will be fully capable of designing right the first time. The system will be sufficiently modular to enable it to effectively incorporate emerging design aids as technology progresses.

The ULCE programs will demonstrate elements of generic design tools, data exchange standards, software, and functional design specifications for implementing ULCE on weapon system acquisition programs scheduled for start in 1995 and beyond. The newly designed engineering curricula that are part of the RAMCAD Software Development Program will prepare new engineers for taking maximum advantage of the ULCE environment.

ULCE also affords a solution to improving domestic industrial productivity and International Competitiveness of US goods. ULCE's development of a design engineering environment in which competing design requirements (often addressed by heterogeneous computers and computerized design aids) are optimized to provide solutions to Readiness and Sustainability issues are also perfectly suited to solve those design related issues that can substantially improve American products in international trade. Such improvements require improved quality at lower cost, while at the same time offering significant buyer protection with extended warranties. This equates to the same issues that effect the ULCE objectives. As an example, the elimination of design errors before they need to be "fixed" on the assembly line applies to all design disciplines, including performance, producibility, quality, manufacturing, and scheduling efficiency; these all lower production costs. Designing for Ease of Maintenance provides for Ease of Assembly and facilitates assembly line testing; thus lowering costs and precluding the compromise of design quality on the assembly line. Designing for Reliability provides for products that work as expected, and that can be warranted without increase in cost. Other specific design issues may be also

addressed during the active design phase by virtue of the modular, adaptive nature of the integration and optimizing techniques to be developed.

Industry, in keeping abreast with the ULCE development, will have conducted parallel activities such that they will, to a large extent, be ready and capable to employ the principles of a total ULCE environment in the mid-to-late 1990s. Industry's application of ULCE will significantly reduce design-to-manufacture lead times, reduce prototyping requirements, reduce costs, and improve supportability.

D. THE INCEPTION FOR ULCE

Attention given design inadequacies essentially started with DoD Directives 5000.1 and 5000.39, which demanded that the acquisition process place reliability, maintainability, and logistic supportability design considerations on an equal level with those for performance, cost, and schedule. Studies conducted by industry associations and government agencies over the past decade have identified that decisions made early in the design of a weapon system or equipment have a significant, often adverse effect on readiness and supportability. Recent demands for more sophisticated performance have increased system design complexity. At the same time projected battle turn-around times have decreased, causing readiness and supportability to become even more critical issues.

As an example, the Air Force has set a goal for the year 2000 of operating increasingly sophisticated weapon systems out of bare bases in remote areas. If it is to meet this goal, then a quantum improvement is required in the supportability (Reliability, Maintainability, Testability, etc.) characteristics of its weapon systems. The iterative analyses-design feedback cycles needed to properly address these issues have increased almost exponentially--demanding specialized skills, incurring high costs, and adversely impacting shrinking development schedules. Consequently, addressing oversights and problems discovered after a design is frozen has become concurrently more difficult and expensive than ever before.

The use of computer techniques to help in improving supportability characteristics is based in part on the well known success of computer aided engineering (CAE) technologies in improving the performance and producibility characteristics of aircraft. Recently, the National Academy of Science produced a study of the benefits accruing to companies that are well advanced in computer integrated manufacturing (CIM). These technologies were shown to result in a more accurate and producible design that made quantum improvements in the efficiency of the manufacturing process. There is every reason to believe that a similar approach to integrating R&M with design would produce similar large benefits in reducing field support requirements.

In the summer of 1985, the Secretary and the Chief of Staff of the U.S. Air Force directed a comprehensive study to identify new technologies with exceptional promise for improving the Air Force's future warfighting capabilities. The results of that study were identified as Project FORECAST II. Seventy initiatives were identified as holding promise to revolutionize the way the Air Force carries out its mission in the 21st century, guaranteeing continued technological supremacy over any potential adversary. Each of these initiatives is recognizably essential to improvements in one or more of the following six broad categories into which Project FORECAST II recommendations were divided:

a. Propulsion and power
b. Vehicles, structures, and materials
c. Electronics and optics
d. Weapons
e. Information, computation, and displays
f. System acquisition and support.

Issues dealing with effecting design attributes with which to attain the desired improvements in the six categories have a common objective, namely that of including appropriate considerations for each design attribute within the design process. This objective is dealt with by the Unified Life Cycle Engineering Initiative PT-32. (See Appendix C for full text.)

E. REQUIRED TASKS

The many tasks required to successfully transform the ULCE objective to practical application and industry acceptance are shown in Figure ES-1. These are grouped into the following broad goals:

a. Develop solutions to the technical issues associated with an ULCE environment,
b. Develop new and missing design aiding techniques,

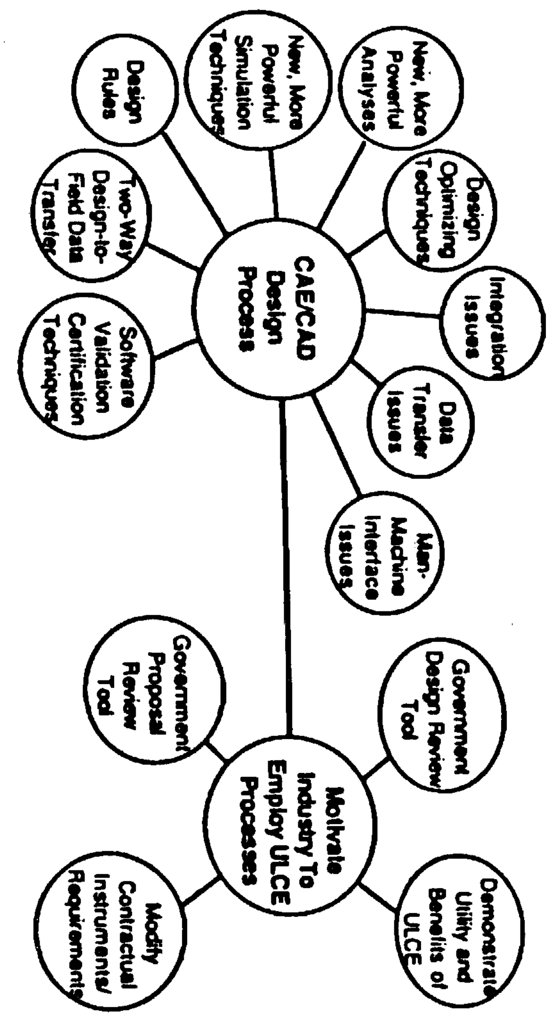


Figure ES-1. ELEMENTS REQUIRED FOR AN ULCE ENVIRONMENT

c. Develop techniques for validating and certifying computerized analyses and design aiding techniques;
d. Motivate industry to employ ULCE processes;
e. Transfer to potential Government and Industry users; and
f. Motivate academia to perform ULCE related basic research and train future engineers in this concept.

Of the elements shown, integration, design optimization, and data transfer are the critical technology issues because they affect the successful application of all the others. The initial ULCE effort will focus on these technology issues.

F. IMPLEMENTATION

There are a number of ongoing Government programs of interest to ULCE, particularly those under the coordination of the working panel of R&M in CAD (RAMCAD) formed by the Joint Logistic Commanders' (JLC) Joint Policy Coordinating Group (JCPG) on Logistics Research, Development, Test, and Evaluation. These are all discussed in the PT-32 description (Appendix C). They, together with several other Project FORECAST II issues, are closely related to technologies to be addressed by ULCE in meeting its objectives and will form a part of the ULCE implementation planning as described herein.

To ensure that research related to the issues addressed by ULCE result in meeting its objective, an ULCE Implementation Team has been established to provide technical direction, guidance, and advocacy for the execution and demonstration of all ULCE programs. The ULCE Implementation Team consists of an ULCE Steering Group, an ULCE Technical Advisory Group (TAG), and the Institute for Defense Analyses (IDA). Technical synergism among the ULCE programs will be elicited by forming an association (ULCE association) of participating USAF organizations with those industries and universities involved in the RAMCAD software development, the RAMCAD supportive tasks implemented by the Institute for Defense Analyses (IDA), and similar organizations that may participate in the future.

A steering group composed of representatives of the Headquarters Office of Primary Responsibility (HQ OPR), Field OPR, and Field Office(s) of Coordinating

Responsibility (OCR) has been organized to serve as the ULCE Program directing body. The ULCE Steering Group consists of representatives from the following offices:

The ULCE HQ OPR, Mr. Randy Meeker (AFSC/DLSR);

The ULCE Field OPR and Chairman of the ULCE Steering Group, Dr. Walter Reimann (AFWAL/MLTC);

The ULCE OCRs, AFWAL/ML, AFHRL/LR, RADC/RB, AFSC/DL, AFWAL/FI, AFOSR/NM, and ASD/EN.

Figure ES-2 provides an overview of the ULCE implementation planning. The development programs are grouped into:

a. Information Management related;
b. Decision Aids related; and
c. Design Aids related.

G. PLANNING DETAILS

Planning details are dynamic, and will become progressively more specific as technical interchange meetings with the developers identify, and developers agree to, specific issues that need to be addressed in more detail or that require changes. These details will be added to periodic revisions of this document. This issue of the ULCE Implementation Plan provides the ULCE Steering Group's initial recommendations for proceeding synergistically along the direction of the individual ULCE projects described herein.

GOVERNMENT PROGRAMS OF INTEREST TO UNIFIED LIFE-CYCLE ENGINEERING (U)

(Table UNCLASSIFIED)

Program	Agency/Principal	Time	Funds ($K)
ML-7.8 Manufacturing Science	AFWAL/ML	83-87	2,000
Reliability Prediction	Army Belvoir R&D Cntr C. Meese	85-89	7[illegible]0
Integrated Design Engineering Analysis	Army/ARDC T. E. Bevelock	86-88	2,400
CAE Tools for Testability	Navy/NOSC D. Hall	84-87	100
TRIMOD (Testability Tradeoff)	Navy/NOSC D. Hall	85-86	200
CALSA (Logistic Support Analysis)	Navy/NOSC A. Knight	85-88	1,350
Avionics Expert System Prototype	AFWAL G. Kurylowich	85-90	1,700
Integrated Design Support System	AFWAL T. N. Bernstein	84-91	2,400
Unified Data Base For Logistics	AFHRL T. L. Peasant	85-88	6,100
Crew Chief	AFHRL A. R. Winn	85-89	4,100
Integrated Design Support	AFWAL/AFHRL (Joint) T. N. Bernstein	84-91	12,000
MLCAD	AFHRL A. E. Herner	85-90	10,900
WS/MPT Requirements Forecasting	AFHRL L. Looper	88-93	20,000
CAD-BIT	RADC T. Oxford	86-87	360
CAD Testability Modeling	RADC/NOSC T. Oxford/J. Bussert	85-86	300
Automated FMEA	RADC T. Oxford	86	IH
Integrated Environmentally Engineered Electronics	AFWAL A. Burkhard	65-91	21,810
Reliability for Real Systems Initiative	AFOSR B. Woodruff	84-87	6,000

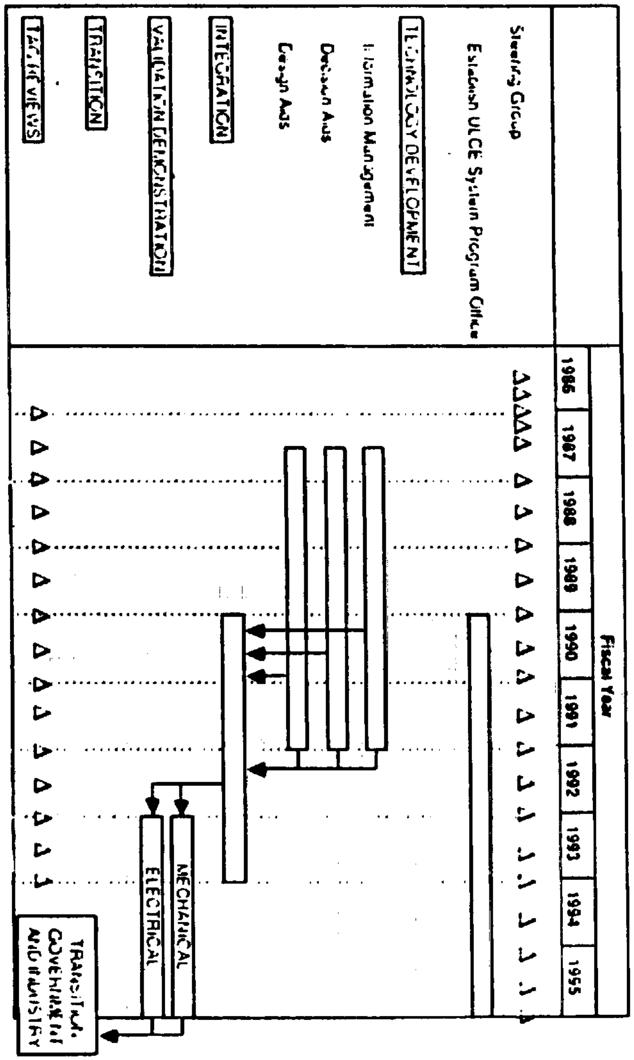
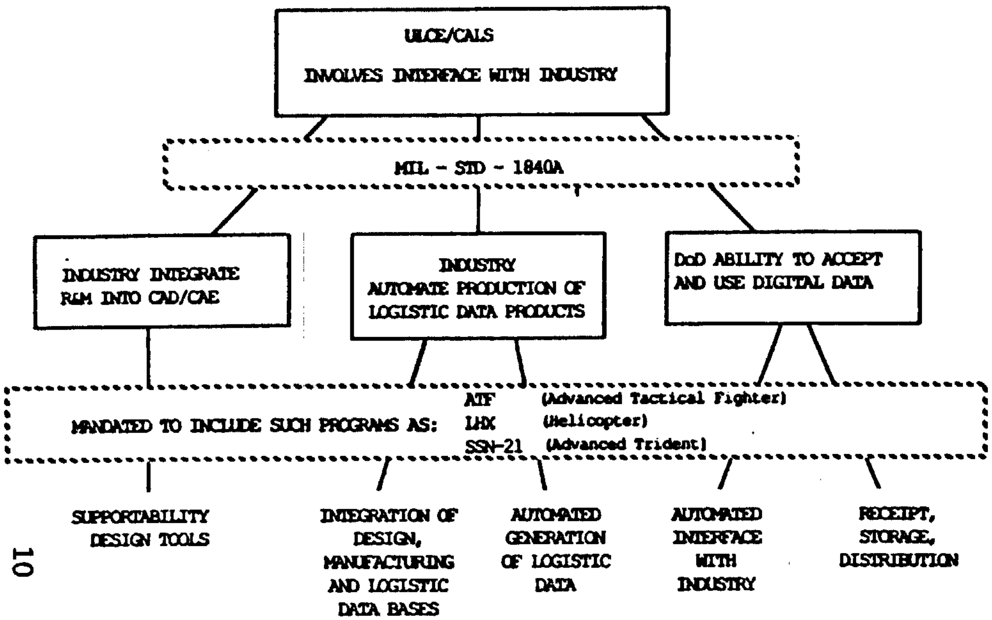


Figure ES-2
ULCE IMPLEMENTATION PLANNING ROADMAP



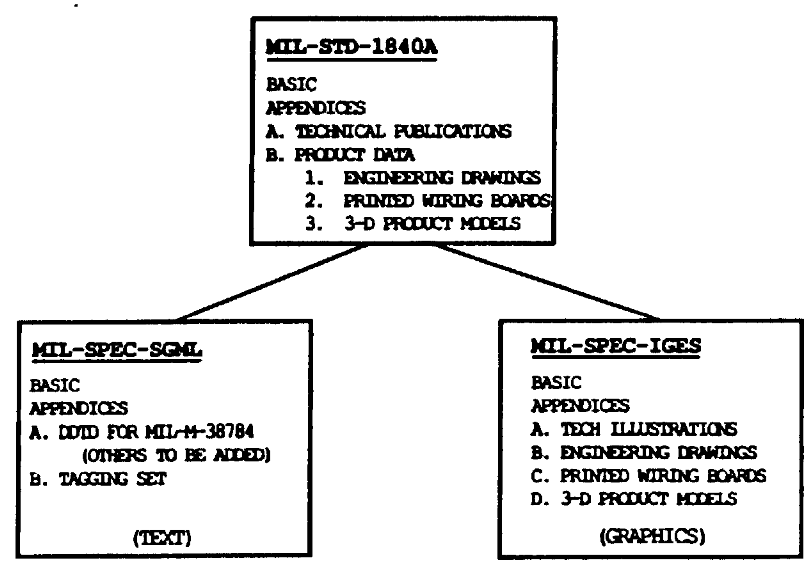
MIL-STD-1840A will provide the basis for DATA FORMATS for all of the systems discussed, and all future systems to be developed.

Provides standards for both text and graphical data.

Has been mandated to programs such as:

ATF
LHX
SSN-21

IDSS IMPLEMENTED BY THIS NEW MIL-STD



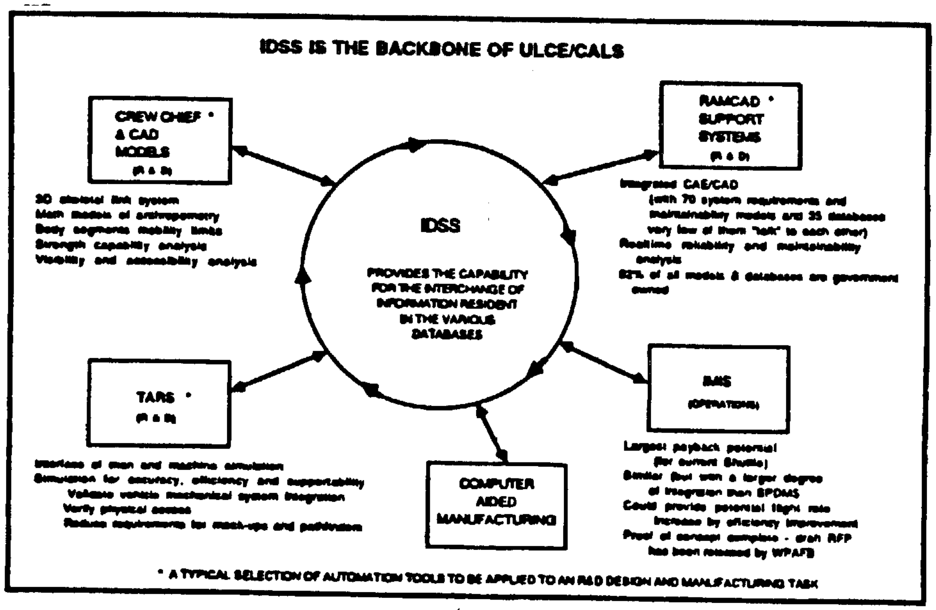
ULCE is a WPAFB term.

Air Force Logistics calls the same activity "CALS" (Computer Aided Logistics Support).

ULCE contains the basic computer aided tools required to support the new design methods.

MIL-STD-1840A provides the basis for product data interchange.

To achieve maximum effect from ULCE/CALS requires that NEW management techniques be placed in effect and compliance must be required by all — from the TOP down.



MIL-STD-1840A
24 March 1987

SUPERSEDING
MIL-STD-1840 (USAF)
11 SEPTEMBER 1986

NOTE: This draft, dated 24 March 1987, prepared by the OSD CALS Office has not been approved and is subject to modification.

DO NOT USE PRIOR TO APPROVAL. (Project ILSS-0023)

MILITARY STANDARD

AUTOMATED INTERCHANGE OF TECHNICAL INFORMATION

AMSC NA ILSS

Distribution Statement A: Approved for public release; distribution is unlimited.

1. SCOPE

1.1. Purpose. The purpose of this standard is to define the mechanisms for transferring and storing in digital form, the technical information necessary for the logistic support of a weapon system throughout its life cycle. The term technical information is used here to include technical documents such as training and maintenance manuals with their associated graphical illustrations, product definition data such as the engineering drawings and specifications which are part of the traditional technical data packages used for item acquisition, and the evolving product data concept which provides for transferring and storing, in computer usable form, all of the product information necessary to the acquisition process.

The initial area addressed by this standard is automating the creation, storage, retrieval, and delivery of hard copy products such as technical manuals and engineering drawings; however, this does not exploit the full potential of emerging computer-based technologies. Solid modeling for system design, interactive retrieval and use of technical information, expert systems (artificial intelligence), and other potential computer applications for weapon systems of the future can be addressed by extending this standard as needed.

1.2. Scope. The standards selected for implementation by this document are for use in applications where the digital data for weapon systems support is being transferred between elements of the Department of Defense, other government agencies, and industry.

This standard establishes the format, content, and procedures for the transfer of digital technical information and is applicable in all cases where the information can be prepared and received in the form of ASCII text files, product data definition files, raster image files, or graphics files. The standard is not restricted in any way in its application.

CONTENTS

CONTENTS - Continued.

CONTENTS - Continued.

CONTENTS - Continued.

CONTENTS - Continued.

APPENDIX A
FILE STRUCTURE FOR TECHNICAL PUBLICATION APPLICATION

CONTENTS

APPENDIX B
FILE STRUCTURE FOR PRODUCT DATA APPLICATION

CONTENTS

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6.2 DEMING'S MANAGEMENT PRINCIPLES

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THE DEMING ROUTE TO QUALITY AND PRODUCTIVITY
by William W. Scherkenbach

POINT 1
Create constancy of purpose toward improvement of product and service, with the aim to become competitive, stay in business, and provide jobs.

POINT 2
Adopt the new philsophy. We are in a new economic age, created by Japan. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.

POINT 3
Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.

POINT 5
Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.

POINT 12
Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibiity of supervisors must be changed from stressing sheer numbers to quality. Remove barriers that rob people in management and engineering of their right to pride of workmanship. This means, inter alia, abolishment of the annual merit rating and of management by objective.

POINT 8
Drive out fear, so that everyone may work effectively for the company.

POINT 9
Break down barriers between deparments. People in research, design, sales, and production must work as a team to foresee problems of production and in use that may be encountered with the product or service.

POINT 10
Eliminate slogans, exhortations, and targets for the work force that ask for zero defects and new levels of productivity.

POINT 11
Eliminate work standards (quotas) on the factory floor. Substitute leadership. Eliminate management by objective. Eliminate management by numbers, numerical goals, substitute leadership.

POINT 7
Institute leadership. The aim of leadership should be to help people, machines and gadgets to do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.

POINT 6
Institute training on the job.

POINT 13
Institute a vigorous program of education and self-improvement.

POINT 4
End the practice of awarding business on the basis of price tag. Instead, minimize total cost. Move toward a single supplier for any one item on a long-term relatinship of loyalty and trust.

POINT 14
Put everybody in the organization to work to accomplish the transformation. The transformation is everybody's job.

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DR. DEMING'S CONCEPTS

Dr. Deming has a number of concepts related to the management use of statistical techniques to improve quality and productivity. The most important of these are:

- The fundamental philosophy associated with the economic production of goods must be based on defect PREVENTION rather than defect DETECTION. This approach requires a system of PROCESS CONTROL, which can only be effectively implemented through STATISTICAL TECHNIQUES. Decisions to modify or adjust processes must be based on statistical evidence, such as control chart data. Reliance on INSPECTION for quality control is both ineffective and inefficient.

- MANAGEMENT must be dedicated to the ONGOING improvement of quality not simply a one-step improvement to an acceptable plateau. Management must be willing to implement changes in the ways a company does business in order to achieve that quality improvement.

- Interpretation of statistical data through such techniques as control charts can help distinguish between COMMON and SPECIAL causes of problems:

- COMMON CAUSES are due to the "system" and can be corrected only by management. They typically account for about 85% of quality problems. The "system" includes all general aspects of the business such as product engineering, manufacturing/assembly, purchasing, marketing, etc. All these activities must share in a company's quality commitment and participate in the resolution of problems.

- SPECIAL CAUSES relate to an individual process itself and can be resolved by the local people involved (e.g., operators, supervisors, maintenance people, etc.). Special causes typically account for about 15% of problems. Employees must be given adequate information to solve problems, including the cost of defects and training in statistical techniques.

- QUALITY and PRODUCTIVITY are not conflicting goals; improvements in quality will also result in productivity gains.

- Similar to Japanese practice, relations with SUPPLIERS must be based on mutual partnership that provides a balance among quality, delivery and price goals rather than on price-based competition alone. Since suppliers significantly affect product quality, suppliers should be encouraged to consider the use of statistical techniques. Training should be provided if necessary.

- Such concepts as work standards, goals and acceptance standards cannot in and of themselves improve quality. Only action based on statistical data can improve quality and productivity.

- Good quality does not mean achieving perfect quality but rather a CONSISTENT and PREDICTABLE QUALITY LEVEL WHICH MEETS THE NEEDS OF THE MARKETPLACE.

Source: Ford Motor Company, Product Quality Office, December 1981

DEMING'S FOURTEEN OBLIGATIONS OF MANAGEMENT

1. Create constancy of purpose.
2. Adopt the new philosophy.
3. Cease dependence on mass inspection.
4. Eliminate suppliers that cannot provide statistical evidence of quality.
5. Find problems. Continue to improve the system.
6. Institute modern methods of training on the job.
7. Improve methods of supervision of production workers.
8. Drive out fear, so that everyone may work effectively for the company.
9. Break down barriers between departments.
10. Eliminate numerical goals, posters, slogans for the work force.
11. Eliminate work standards that prescribe numerical quotas.
12. Remove barriers that stand between the hourly worker and his right to pride of workmanship.
13. Institute a vigorous program of education and training.
14. Create a structure in top management that will push every day on the above 13 points.

W. EDWARDS DEMING

Born in 1900. Grew up in a small town in Wyoming. Attended the University of Wyoming majoring in electrical engineering. Went on to earn a Ph.D. in mathematical physics at Yale.

During the twenties he worked for a time at Western Electric where he began his work on fourteen points. During the 1930's Deming worked to help others understand the new science of statistical process control. Walter Shewhart of Bell Labs was a great influence. Deming was among a few to understand Shewhart. During the 1940's his achievements began with his work at the Bureau of the Census. During World War II he helped defense industries apply statistical quality controls. Around 1948 he made his first visit to Japan to speak with scientists and engineers. He found much statistical talent and interest. In 1950 he presented his ideas to the major industrialists called together by Ishikawa for the purpose of improving the national quality image.

In 1979 he became a consultant to the Nashua Corporation where he would later be called by Bill Conway, then president and CEO, "The Father of the Third Wave of the Industrial Revolution."

NBC-TV presented a white paper called "If Japan Can -- Why Can't We?", a documentary that featured Deming's philosophy as a new way to improve quality and productivity.

He thus came into clearer focus here in America. It wasn't long before top executives at the major automotive companies were anxious to hire him as their consultant.

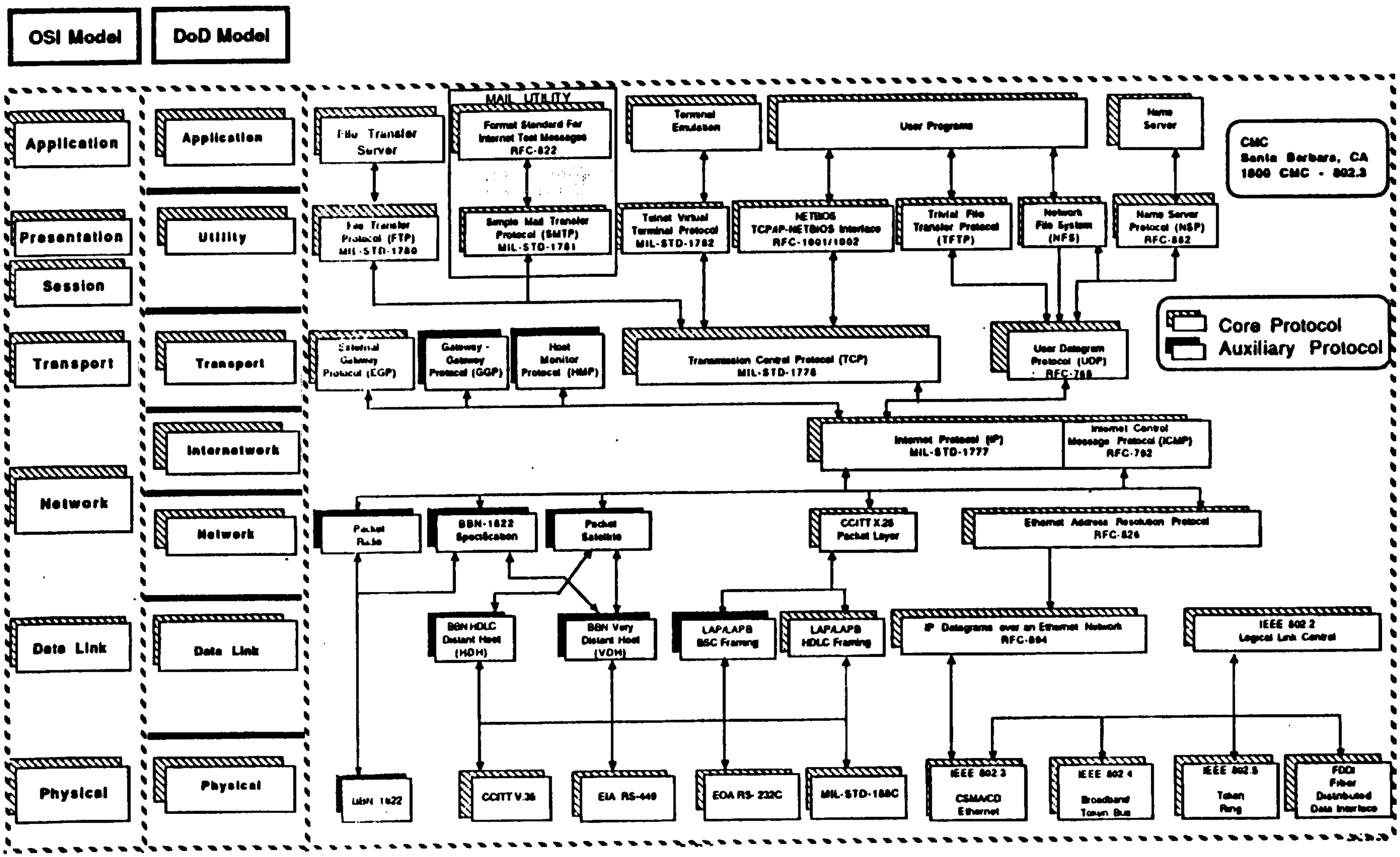
He is widely sought by many companies wanting to learn his "secrets" of Japanese success. He directs them to follow his 14-points and learn statistical process control.

He says its "so simple."

S G O E/T STUDY
PHASE-2 FINAL
PRESENTATION
by BOEING

DoD INTERNET ARCHITECTURE

PRESENTED AT
KSC
APR. 6, 1988



NASA mixed fleet cargo

SPACEPORT NEWS
March 25, 1988
Page 3

Local Launches
August 1988 through December 1990

Date	Mission and Vehicle	Prime Cargo
August 1988	STS-26 Discovery	Tracking and Data Relay Satellite (TDRS-C)
3rd Quarter 1988	Delta 183	DOD
October 1988	STS-27 Atlantis	DOD
September 1989	Atlas Centaur 68	U.S. Navy Fleet Communications Satellite (FLTSATCOM-F8)
January 1989	STS-29 Discovery	TDRS-D
March 1989	STS-28 Columbia	DOD
April 1989	STS-30 Atlantis	Magellan Venus Global Mapper
June 1989	STS-31 Discovery	Hubble Space Telescope
July 1989	STS-32 Columbia	Long Duration Exposure Facility (LDEF) retrieval and Hughes Geosynchronous Communications Satellite (SYNCOM IV-5)
August 1989	STS-33 Atlantis	DOD
October 1989	STS-34 Discovery	Galileo Jupiter Probe
November 1989	STS-35 Columbia	Ultraviolet Astronomy Telescope (ASTRO-1) and Broad Band X-Ray Telescope (BBXRT)
December 1989	STS-36 Atlantis	DOD
February 1990	Delta	Roentgen Satellite (ROSAT)
February 1990	STS-37 Discovery	DOD: Cryogenic Infrared Radiance Instrument for Shuttle (CIRRIS), Infrared Background Signature Survey (IBSS), and Teal Ruby infrared sensor
March 1990	Atlas Centaur	Geostationary Operational Environmental Satellite (GOES-I)
March 1990	STS-38 Columbia	Space Life Sciences Laboratory (SLS-1)
March 1990	STS-39 Atlantis	Gamma Ray Observatory (GRO)
May 1990	STS-40 Discovery	DOD
June 1990	Atlas Centaur	Combined Radiation Release Experimental Satellite (CRRES)
June 1990	STS-41 Columbia	Starlab (DOD Spacelab experiments)
July 1990	STS-42 Atlantis	TDRS-E
September 1990	STS-43 Columbia	Atmospheric Laboratory for Applications and Science (ATLAS-1)
October 1990	STS-44 Discovery	Ulysses International Solar Polar Mission
December 1990	Atlas Centaur	GOES-J

For planning only; dates subject to change.

6.3 DESIGN / BUILD TEAM CONCEPTS

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6.3 DESIGN / BUILD TEAM CONCEPTS

This New Management technique (Design/Build Teams) will shatter existing "Rice Bowls".

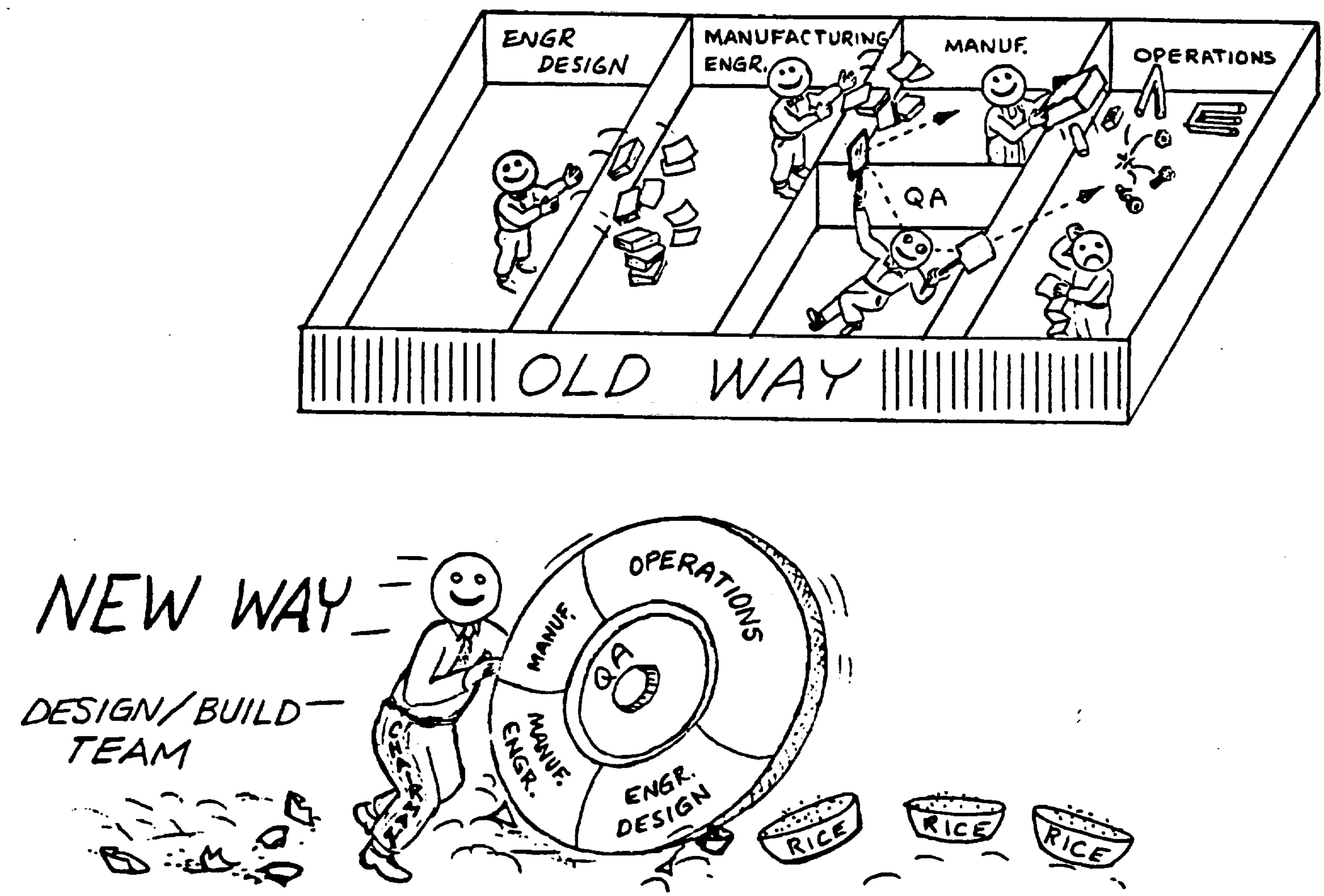
Will instill a real feeling of team participation in ALL project Members.

Is also the most difficult to achieve because it requires EACH project member to:

Desire -- the change in the way of doing business

Belief -- that change can be accomplished within the system

This requires firm leadership from the TOP.



MANAGEMENT TECHNOLOGY CARTOON
(Boeing Aerospace Operations)
Figure 6

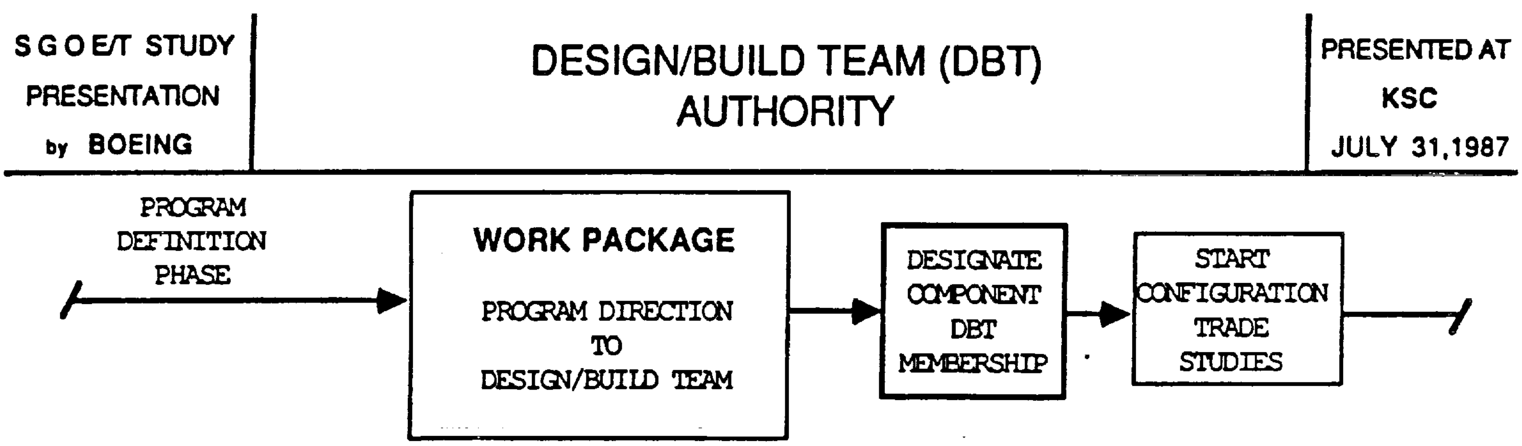
6.3 DESIGN / BUILD TEAM CONCEPTS

DESIGN/BUILD TEAM (DBT) AUTHORITY

All Design/Build Teams (DBT) are initiated by joint memo from Program Engineering and Operations Management.

The memo establishes each design package and the schedule for its implementation by the assigned team.

It is the responsibility of the Engineering and Manufacturing management to identify the DBT co-chairmen. The DBT co-chairmen will consist of one person from Engineering Project Design and one from Manufacturing Engineering.



- o COMPONENT CONFIGURATION
- o WEIGHT
- o FUNCTIONAL REQUIREMENT
- o BASELINE SOW (STATEMENT-OF-WORK)
- o BASELINE COMPONENT COST
- o BASELINE MARKET VALUE
- o TRADE STUDY FACTORS
- o SELECT DBT CO-CHAIRMEN (ENGR. & MFG.)
- o SCHEDULE
- o AUTHORITY OF DBT

PROGRAM DEFINITION PHASE
Figure 7

6.3 DESIGN / BUILD TEAM CONCEPTS

DESIGN/BUILD TEAMS (STRUCTURE)

New management technology is required to achieve maximum effect from computer aided design tools.

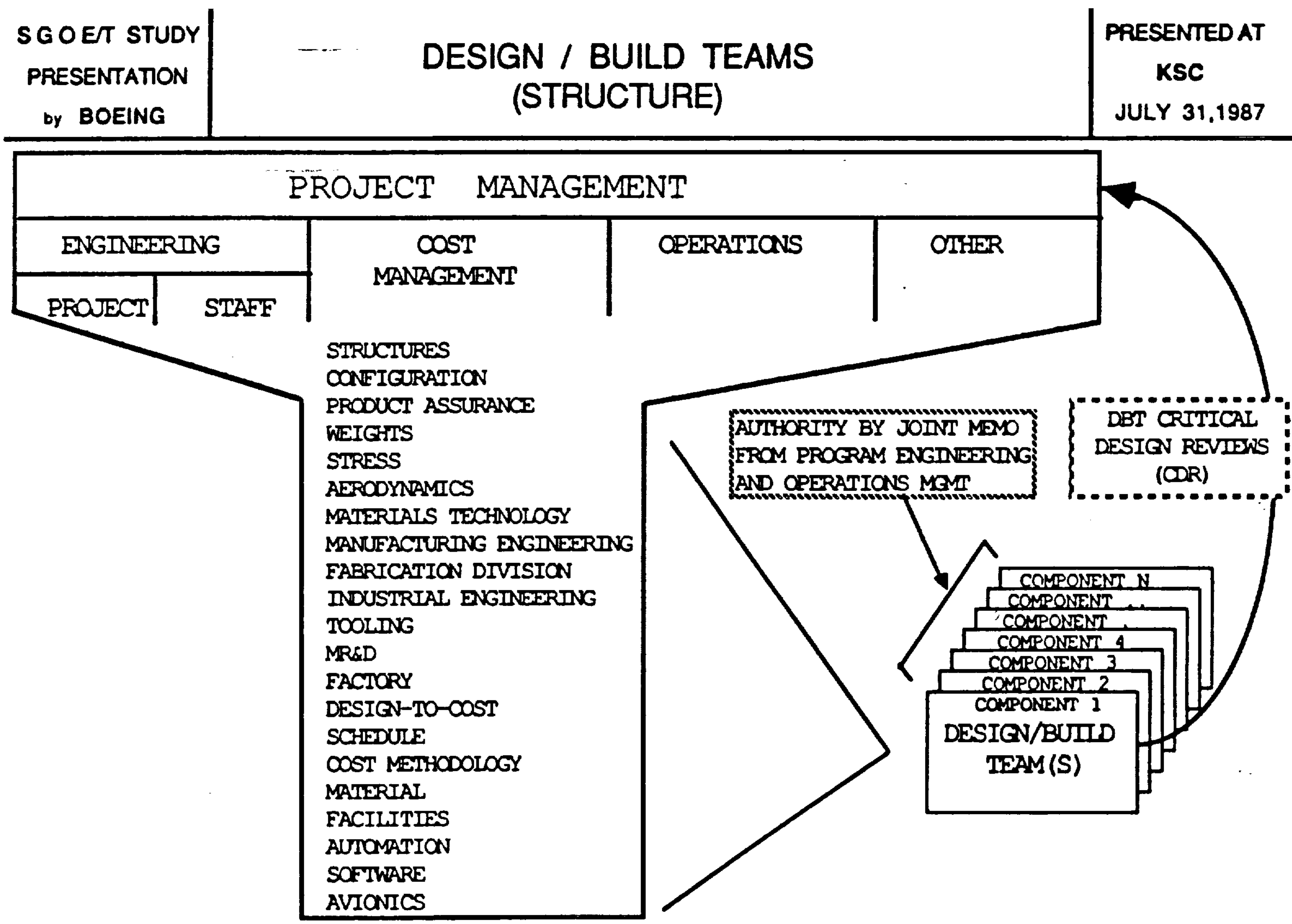
New design management is the hardest part to establish but without it the new design methods will not work.

Design Build Teams DO NOT report back to functional fathers. They have complete design responsibility, within the team, for their specific assignment per Joint Authority Memo.

Design/Build Team(s) reports directly to Project Management.

Requires larger effort on the part of System Engineering to establish firm operational, performance and cost requirements to the subsystem level; i.e., see DBT Authority on preceding page.

These new management methods are in place within Boeing. Pilot projects have proven their value.



PROJECT MANAGEMENT
Figure 8

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6.4 NASA-A.F. LAUNCH/FLIGHT/CONFIGURATION STATISTICS

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*** SHUTTLE PAYLOAD FLIGHT ASSIGNMENTS ***
OCTOBER 1987

FLT	DATE ORBITER	INCL ALT	CRW DUR	PAYLOAD	CARRIER	SECONDARY PAYLOADS*	CREW ASSIGNMENT
26	88 6 2 DISCOVERY	28.5 160	5 4	TDRS-C	IUS	ADSF-2 ARC-2 ELRAD HMI-1 IEE-2 IRCFE MLE-1 PCG-II PVTOS-2 SL-82-04 SL-82-05	C: F. H. HAUCK (CAPT., USN) P: R. O. COVEY (LT. COL., USAF) MS: J. LOUNGE (M.S.-ASTROPHYSICS) MS: G. NELSON (PH.D. ASTRONOMY) MS: DAVID HILMERS (MAJ., USMC)
27	88 9 8 ATLANTIS	XX X	5 X	DOD			C: R. L. GIBSON (CDR., USN) P: GUY S. GARDNER (LT COL, USAF) MS: R. M. MULLANE (COL., USAF) MS: JERRY L. ROSS (LT. COL, USAF) MS: W. M. SHEPHERD (CDR., USN)
28	88 12 1 COLUMBIA	XX X	X X	DOD			
29	89 2 2 DISCOVERY	28.5 160	5 4	TDRS-D	IUS		
30	89 4 27 ATLANTIS	28.9 160	5 4	MAGELLAN	IUS		

* SHUTTLE SECONDARY PAYLOADS ARE SHOWN ONLY FOR SHUTTLE FLIGHTS ON WHICH THEY ARE FORMALLY ASSIGNED. THESE ASSIGNMENTS ARE MADE APPROXIMATELY 12 MONTHS PRIOR TO LAUNCH.

*** SHUTTLE PAYLOAD FLIGHT ASSIGNMENTS ***
OCTOBER 1987

FLT	DATE ORBITER	INCL ALT	CRW DUR	PAYLOAD	CARRIER	SECONDARY PAYLOADS	CREW ASSIGNMENT
31	89 6 1 DISCOVERY	28.5 320	5 5	HST	UNIQUE		
32	89 6 29 COLUMBIA	28.5 190	7 7	ASTRO-1	1G+2 PAL		
33	89 8 24 ATLANTIS	XX X	X X	DOD			
34	89 10 9 DISCOVERY	34.3 145	5 4	GALILEO	IUS		
35	89 11 9 COLUMBIA	28.5 160	5 5	GPS-1 IBSS	PAM-D2 SPAS		
36	89 12 7 ATLANTIS	XX X	X X	DOD			
37	90 3 1 COLUMBIA	28.5 160	5 5	GPS-2 SYNCOM IV-5	PAM-D2 UNIQUE		
38	90 3 29 DISCOVERY	33.4 175	7 7	STARLAB	1M+1 PAL		
39	90 4 26 ATLANTIS	XX X	X X	DOD			

*** SHUTTLE PAYLOAD FLIGHT ASSIGNMENTS ***
OCTOBER 1987

FLT	DATE ORBITER	INCL ALT	CRW DUR	PAYLOAD	CARRIER	SECONDARY PAYLOADS	CREW ASSIGNMENT
40	90 6 4 COLUMBIA	28.5 160	5 4	GRO			
41	90 7 2 DISCOVERY	XX X	X X	DOD			
42	90 8 2 ATLANTIS	28.5 160	5 4	TDRS-E	IUS		
43	90 8 31 COLUMBIA	28.5 160	5 7	SKYNET-4A EURECA-1L	PAM-D2		
44	90 10 5 DISCOVERY	28.5 160	5 4	ULYSSES	IUS/PAM		

*** SPACE SHUTTLE FLIGHTS BEYOND STS 44 ARE UNDER REVIEW PENDING RESOLUTION OF DOD REQUIREMENTS.
SEE SECTION 5.0 PAYLOAD REQUESTS

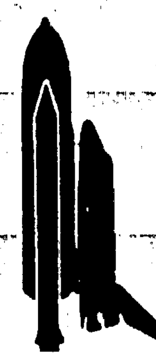
NASA Information Summaries

National Aeronautics and
Space Administration

PMS 009 (KSC)
MAY 1986

Orbiter Flights To Date

25 TOTAL FLIGHTS



CHALLENGER OV-099

Flight	Dates
51-L	*1/28/86
61-A	10/30/85 11/ 6/85
51-F	7/29/85 8/ 6/85
51-B	4/29/85 5/ 6/85
41-G	10/ 5/84 10/13/84
41-C	4/ 6/84 4/13/84
41-B	2/ 3/84 2/11/84
STS-8	8/30/83 9/ 5/83
STS-7	6/18/83 6/24/83
STS-6	4/ 4/83 4/ 9/83

COLUMBIA OV-102

Flight	Dates
61-C	1/12/86 1/18/86
STS-9	11/28/83 12/ 8/83
STS-5	11/11/82 11/16/82
STS-4	6/27/82 7/ 4/82
STS-3	3/22/82 3/30/82
STS-2	11/12/81 11/14/81
STS-1	4/12/81 4/14/81

DISCOVERY OV-103

Flight	Dates
51-I	8/27/85 9/ 3/85
51-G	6/17/85 6/24/85
51-D	4/12/85 4/19/85
51-C	1/24/85 1/27/85
51-A	11/ 8/84 11/16/84
41-D	8/30/84 9/ 5/84

ATLANTIS OV-104

Flight	Dates
61-B	11/26/85 12/ 3/85
51-J	10/ 3/85 10/ 7/85

NO. OF FLIGHTS

*UNSUCCESSFUL

STS MISSION SUMMARY: STS-1 THRU 51-L

Key (C) = Commander
(P) = Pilot
(MS) = Mission Specialist
(PS) = Payload Specialist

Backup crews listed below dotted line

FLIGHT	CREW	LAUNCH PREPS	LAUNCH	LANDING	MISSION
STS 1 Columbia	John W. Young, C Robert L. Crippen, P .... Joseph H. Engle, C Richard H. Truly, P	OPF 610 days VAB 35 days Pad 105 days	April 12, 1981, 7 a.m. EST, Kennedy Space Center, Fla. Attempt on April 10 scrubbed because of timing skew in orbiter general purpose computer system.	April 14, 1981, 10:21 PST, Edwards Air Force Base, Calif. Mission duration, two days, 6 hours, 20 minutes, 52 seconds. Travelled 933,757 miles in 36 orbits. Wheels down to stop, 8,993 feet. Returned to KSC April 28.	Major Space Shuttle systems were tested successfully. Orbiter sustained some tile damage on launch and some damage from overpressure wave created by the solid rocket boosters. 16 tiles lost and 148 damaged.
STS 2 Columbia	Joseph H. Engle, C Richard H. Truly, P .... Thomas K. Mattingly, C Henry W. Hartsfield, P	OPF 103 days VAB 21 days Pad 74 days	Nov. 12, 1981, 10:10 a.m. EST, Kennedy Space Center, Fla. First set for Oct. 9 but delayed by spill of nitrogen tetroxide during loading of forward reaction control system. An attempt Nov. 4 scrubbed when countdown computer called for a hold in the count because of apparent low reading on fuel cell oxygen tank pressures; during hold high oil pressures were discovered in two of the three auxiliary power units that operate hydraulic system. Filter replacement required delaying launch until Nov. 12 at 7:30 a.m. Further delay of three hours because of need to replace a multiplexer/demultiplexer. Modifications to launch platform to overcome over-pressure problem were found to be effective.	Nov. 14, 1981, 1:23 p.m., PST, Edwards Air Force Base, Calif. Mission duration, two days, six hours, 13 minutes and 12 seconds. Travelled 933,757 miles in 36 orbits. Wheels down to stop, 7000 feet. Returned to KSC Nov. 25, 1981.	Flight was cut from its planned duration of five days because of failure of one of three fuel cells that produce electricity and drinking water. Remote manipulator system was tested for first time. Mission scientists satisfied with the data from "earth-looking" experiments in payload bay. No tiles lost, about a dozen damaged.
STS-3 Columbia	Jack R. Lousma, C Charles G. Fullerton, P .... Thomas K. Mattingly, C Henry W. Hartsfield, P	OPF 70 days VAB 14 days Pad 34 days	March 22, 1982, 11 a.m. EST, Kennedy Space Center, Fla. Launch was delayed one hour by ground support equipment problem.	March 30, 1982, 9:05 MST, Northrup Strip, White Sands, N.M. Traveled 3.3 million miles in 129 orbits. Mission duration, eight days, five minutes. Landing site changed from Edwards Air Force Base, Calif., to Northrup because of wet conditions on the Edwards dry lake bed landing site and delayed one day because of high winds at Northrup. Wheels down to stop, 13,810 feet. Returned to KSC April 6, 1982.	Continued testing of Space Shuttle systems for qualification for operational flight. Extensive testing of the remote manipulator system. Measurement of thermal response of orbiter in various attitudes to sun. Nine OSS-1 experiments flown, plus monodisperse latex reactor, electrophoresis test, heflex bioengineering test and induced environment contamination monitor. First student experiment flown. Problems included space sickness, malfunctioning toilet, thermostat difficulty and unexplained static interfering with crew sleep on ascent. One APU registered overheating but functioned properly on descent. Three communications links lost March 26, 36 tiles lost and 19 damaged.
STS-4 Columbia	Thomas K. Mattingly, C Henry W. Hartsfield, P Following STS-3, back-up crews were no longer named.	OPF 42 days VAB 7 days Pad 33 days	June 27, 1982, 11 a.m. EDT, Kennedy Space Center, Fla. First Space Shuttle to be launched on time and with no delays in schedule.	July 4, 1982, 9:09 a.m. PDT, Edwards Air Force Base, Calif., Mission duration, seven days, 1 hour, nine minutes, 39 seconds. Traveled 2.9 million miles in 112 orbits. Wheels down to stop, 8,000 feet. First landing on a concrete strip, the 15,000-foot long Runway 22 at Edwards. Returned to KSC July 15.	Final STS Research & Development flight. Cargo included the first Getaway Special, a Defense Department payload, and the first commercial experiment, the Continuous Flow Electrophoresis System. Mattingly and Hartsfield took data for two medical experiments on themselves, operated the manipulator arm to swing the Induced Environmental Contamination Monitor around the orbiter, and took photos of lightning activity in the atmosphere below. The two SRBs were lost when they impacted the ocean, but all other mission objectives were achieved.
STS-5 Columbia	Vance Brand, C Robert F. Overmyer, P Dr. Joseph P. Allen, MS Dr. William B. Lenoir, MS	OPF 57 days VAB 11 days Pad 52 days	Nov. 11, 1982 7:19 a.m. EST, Kennedy Space Center, Fla. Lifted off on time with no delays in schedule.	Nov. 16, 1982, 6:33 a.m. PST, Edwards Air Force Base, Calif. Mission duration, 5 days, two hours, 14 minutes, 25 seconds. Traveled 2 million miles in 81 orbits. Landed on concrete runway 22 at Edwards. Wheels down to stop, 9,553 feet. Returned to KSC Nov. 22.	First STS operational mission, first deployment of two commercial communications satellites, Anik C-3 for Telesat Canada, and SBS-C for Satellite Business Systems. First crew of four on an American spacecraft, and first use of mission specialists. Three student experiments, monodisperse latex reactor and West German MAUS getaway special flown. First scheduled "spacewalk" of Shuttle Program cancelled due to space suit malfunctions.
STS-6 Challenger	Paul J. Weitz, C Karol J. Bobko, P Donald H. Peterson, MS Dr. Story Musgrave, MS	OPF 141 days VAB 7 days Pad 126 days	April 4, 1983, 1:30 p.m. EST, Kennedy Space Center, Fla. Liftoff was originally set for Jan. 20, 1983. Postponement of more than two months resulted from detection of hydrogen leak on the No. 1 main engine. Excess hydrogen reading detected in Dec. 18, 1982 Flight Readiness Firing was confirmed to be a leak in the aft engine compartment through a second FRF Jan. 25, 1983. The other main engines were eventually removed to repair fuel line cracks and were reinstalled. A spare engine replaced the original No. 1 engine. An additional launch delay resulted from contamination of the TDRS satellite during a severe storm. Final countdown was uneventful.	April 9, 1983, 10:53 a.m. PST, Edwards Air Force Base, Calif. Mission duration, 5 days, 24 minutes, 32 seconds. Traveled 2 million miles in 80 orbits. Landed on concrete runway 22 at Edwards. Wheels down to stop, 7,300 feet. Returned to KSC April 16.	First flight of the orbiter Challenger. First Tracking and Data Relay Satellite (TDRS—A) deployed on first day of mission. A malfunction of the IUS transfer stage resulted in placement of spacecraft in improper but stable orbit. Planning for corrective action began immediately. First "spacewalk" of the Shuttle program successfully performed by Peterson and Musgrave. EVA lasted 4 hours, 17 minutes. Other cargo CFES, MLR, three Getaway Special canisters. First use of lightweight external tank and lightweight solid rocket booster casings.
STS-7 Challenger	Robert L. Crippen, C Frederick C. Hauck, P John M. Fabian, MS Dr. Sally K. Ride, MS Dr. Norman Thagard, MS	OPF 34 days VAB 5 days Pad 24 days	June 18, 1983, 7:33 a.m. EDT, Kennedy Space Center Fla. Liftoff on time with no delays in schedule.	June 24, 1983, 6:57 a.m. PDT, Edwards Air Force Base, Calif. Mission duration, 6 days, 2 hours, 24 minutes, 10 seconds. Traveled 2.2 million miles in 97 orbits. Landed on runway 23. Wheels down to stop estimated 8,000 feet. Returned to KSC on June 29.	First flight of an American woman into space. Largest flight crew (five members) ever launched into orbit aboard a single craft. Continuing validation of Remote Manipulator System through first deployment and retrieval of a spacecraft, the Shuttle Pallet Satellite (SPAS—01). Crew successfully deployed two communications satellites, Anik C—2 for Telesat Canada and Palapa B—1 for Indonesia. Crew also performed proximity operations conducted with the free flying SPAS—01. Experiments to investigate Space Adaptation Syndrome carried out. First planned landing at KSC was cancelled due to unacceptable weather at the Florida landing site.
STS-8 Challenger	Richard H. Truly, C Daniel C. Brandenstein, P Dale A. Gardner, MS Guion S. Bluford, Jr., MS Dr. William Thornton, MS	OPF 26 days VAB 7 days Pad 28 days	August 30, 1983, 2:30 a.m. EDT, Kennedy Space Center, Fla. Launch was delayed 17 minutes due to weather.	Sept. 5, 1983, 12:40 a.m. PDT, Edwards Air Force Base Calif. Mission Duration, 6 days, 1 hour, 8 minutes, 40 seconds. Traveled 2.2 million miles in 97 orbits. Landed on runway 22. Wheels down to stop at 9,200 feet. Returned to KSC on Sept. 9.	First night launch and landing of a Space Shuttle. First flight of an American Black into space. Successful deployment of the Indian National Satellite, INSAT — 1B, a multipurpose satellite for India. Payload Flight Test Article was used to test the Remote Manipulator System for large-mass payload capability, and to evaluate the elbow, wrist and shoulder joint reaction to higher loads. Biofeedback experiments were conducted. Six rats were flown in the Animal Enclosure Module to observe animal reaction in space. Fourth time for CFES to fly, but first time to use live human cells from a pancreas, a kidney and a pituitary gland. Other cargo: Development Flight Instrumentation Pallet and Getaway Special canisters. Testing between the Tracking and Data Relay Satellite and Challenger using the Ku band antenna. Continued investigations of Space Adaption Syndrome.

STS MISSION SUMMARY SPACE SHUTTLE MISSIONS STS-1 THROUGH 51-L

Key: (C) = Commander (MS) = Mission Specialist
(P) = Pilot (PS) = Payload Specialist
Backup crews listed below dotted line

FLIGHT	CREW	LAUNCH PREPS	LAUNCH	LANDING	MISSION
STS-9 Columbia	John W. Young, C Brewster H. Shaw, P Owen Garriott, MS Dr. Robert A. Parker, MS Dr. Byron K. Lichtenberg, PS Dr. Ulf Merbold, PS (ESA)	Flow A: OPF 81 days VAB 5 days Pad 18 days Flow B: OPF 14 days VAB 5 days Pad 21 days	November 28, 1983, 11:00 a.m. EST, Kennedy Space Center. The launch was delayed one month because of a suspect exhaust nozzle in the right-hand solid rocket booster which was discovered after the Shuttle vehicle had been transported to the launch pad. The Shuttle was moved back to the VAB and demated from its external tank and solid rocket boosters. The suspect nozzle was then replaced, and the entire Shuttle vehicle was restacked.	Dec. 8, 3:47 p.m. PST, on Runway 17 at Edwards Air Force Base California. Mission duration 10 days, 7 hours, 47 minutes. Traveled 4.3 million miles in 167 orbits. Returned to KSC on Dec. 15.	First flight of non-astronaut scientists (2) into space, and first foreigner (representing ESA) to fly on the Shuttle. Flight also marked the first time Shuttle crew members worked around the clock. First Spacelab mission. ESA and NASA jointly sponsored Spacelab 1 flight and contributed investigations which demonstrated the capability for advanced research in space. About 72 separate investigations carried out during the mission in the areas of atmospheric physics and earth observations, space plasma physics, solar physics and astronomy, and materials sciences and technology. Space adaptation syndrome studies were continued.
41-B (10) Challenger	Vance D. Brand, C Robert L. Gibson, P Bruce McCandless II, MS Ronald E. McNair, MS Robert L. Stewart, MS	OPF 67 days VAB 6 days Pad 22 days	February 3, 1984, 8:00 a.m. EST, Kennedy Space Center. Liftoff was originally set for January 29, but was delayed until Feb. 3, when Challenger's auxiliary power units were replaced as a precautionary measure.	Feb. 11, 7:17 a.m. EST, Kennedy Space Center. First landing of a spacecraft at its launch site. Mission duration, 7 days, 23 hours, 17 minutes. Traveled 2.8 million miles in 127 orbits. Landed on Runway 15 at KSC. Wheels down to stop, 10,700 feet. First landing at KSC.	First untethered space walks were performed by astronauts McCandless and Stewart. First in-space use of Manned Maneuvering Unit. West German-built Shuttle Pallet Satellite (SPAS), originally flown on STS-7, became first satellite to be refurbished and flown again. First in-space use of robot arm's Manipulator Foot Restraint. WESTAR VI and PALAPA B-2 satellites were successfully deployed, but probable failure of PAM rocket motors left them in radical low-Earth orbits.
41-C (11) Challenger	Robert L. Crippen, C Francis R. Scobee, P Dr. George D. Nelson, MS Dr. James D. van Hoften, MS Terry J. Hart, MS	OPF 32 days VAB 4 days Pad 19 days	April 6, 1984, 8:58 a.m. EST, Kennedy Space Center.	April 13, 5:38 a.m. PST on Runway 17 at Edwards Air Force Base, California. Mission duration 6 days, 23 hours 40 minutes. Traveled 2.87 million miles in over 108 orbits. Returned to KSC on April 18.	First in-orbit capture, repair & redeployment of a free-flying spacecraft. First operational use of the Manned Maneuvering Unit, Manipulator Foot Restraint & EVA power tools. The attitude control system and coronagraph/polarimeter electronics box on SolarMax satellite orbited in 1980 were replaced. First direct ascent of Space Shuttle. First deployment of Long Duration Exposure Facility, carrying 57 experiments.
41-D (12) Discovery	Henry W. Hartsfield Jr., C Michael L. Coats, P Judith A. Resnik, MS Richard M. Mullane, MS Steven A. Hawley, MS Charles D. Walker, PS	Flow A: OPF 124 days VAB 6 days Pad 56 days 3 days in VAB for orbiter/ET demate Flow B: OPF 16 days VAB 7 days Pad 22 days	Aug. 30, 1984, 8:41 a.m. EDT, Kennedy Space Center, Fla. First set for June 25 but scrubbed during T−9 minute hold due to failure of Discovery's back-up General Purpose Computer (GPC). Attempt on June 26 was aborted at T−4 seconds when GPC detected anomaly in the orbiter's number three engine. Discovery was rolled back to the VAB and OPF and the number three engine was replaced. To preserve the launch schedule of future missions, it was decided to remanifest the 41-D cargo to include payload elements from both the 41-D and 41-F flights, and to cancel the 41-F mission. A third attempt on Aug. 29 was delayed when a discrepancy was noted in the flight software of Discovery's Master Events Controller. Discovery's Aug. 30 launch was delayed six minutes when a private aircraft intruded into a warning area off of Cape Canaveral.	Sept. 5, 6:37 a.m. PDT on runway 17 at Edwards Air Force Base, Calif. Because the mission was Discovery's first flight, the Edwards A.F.B. desert runway was chosen as the primary landing site. Mission duration 6 days, 56 minutes. Traveled 2.21 million miles in 97 orbits. Returned to KSC on Sept. 10.	First flight of the orbiter Discovery. First deployment of three satellites on a single mission. First flight of a commercial payload specialist. First use of lightweight thermal blanket material on Shuttle's exterior. A 105-foot tall solar array became the largest structure ever extended from a spacecraft. Continuous Flow Electrophoresis Experiment was flown and operated over 100 hours during mission. The satellites deployed included Leasat-2, SBS-4 and Telstar 3-C. Heaviest payload carried into orbit at 47,500 lbs. IMAX Motion Picture Camera makes 2nd of three scheduled flights into space.
41-G (13) Challenger	Robert L. Crippen, C Jon A. McBride, P David C. Leestma, MS Sally K. Ride, MS Kathryn D. Sullivan, MS Paul Scully-Power, PS Marc Garneau, PS	OPF 69 days VAB 5 days Pad 23 days	Oct. 5, 1984, 7:03 a.m. EDT, Kennedy Space Center, Fla.	Oct. 13, 12:26 p.m. EDT, Kennedy Space Center. Mission duration 8 days, 5 hours 23 minutes. Traveled 4.3 million miles in 133 orbits.	Largest flight crew ever launched into orbit aboard a single spacecraft. First flight to include two women. Astronaut Kathy Sullivan became the first American woman to walk in space. Bob Crippen became the first astronaut to fly a fourth Shuttle mission. Marc Garneau performed ten experiments dealing with space technology and earth and space science. Garneau also became the first Canadian to fly in space. First demonstration of a satellite refueling technique in space. Earth Radiation Budget satellite was deployed on flight day one and Shuttle Imaging Radar data was recorded throughout the mission. Civilian Navy oceanographer Paul Scully-Power conducted real-time observations of ocean phenomena from space. Other principal payloads included the Large Format Camera and MAPS; an experiment that measured the amount of air pollution which escapes the Earth's atmosphere and enters space.
51-A (14) Discovery	Frederick H. Hauck, C David M. Walker, P Anna L. Fisher, MS Dale A. Gardner, MS Joseph P. Allen, MS	OPF 37 days VAB 5 days Pad 17 days	Nov. 8, 1984, 7:15 a.m. EST. First attempt on Nov. 7 scrubbed during built-in hold at T−20 minutes, due to shear winds in upper atmosphere.	Nov. 16, 7 a.m. EST, Runway 33, Kennedy Space Center. Mission duration 7 days, 23 hours, 45 minutes. Traveled 3.3 million miles in 127 orbits. This was the third Shuttle landing at KSC.	This was Space Shuttle Discovery's second mission in space. It was the first flight ever to deploy two communications satellites and retrieve two other disabled satellites. On Day 2 of Mission, Canadian Communications Satellite Anik D-2 (TELESAT H) was deployed into geosynchronous orbit. On Day 3, the HUGHES 1 (LEASAT IV-1) was deployed into geosynchronous orbit. During the mission, Mission Specialists Joseph Allen and Dale Gardner successfully retrieved two malfunctioning satellites during extravehicular activities (EVA). Wearing jet-propelled Manned Maneuvering Units (MMU), the astronauts retrieved the PALAPA B-2 and WESTAR VI satellites. Mission Specialist Anna Fisher operated the Canadian-built Remote Manipulator System (RMS), a mechanical arm that grappled the satellites and deposited them within the payload bay. The two satellites had originally been deployed during Mission 41-B in February 1984. Use of the satellites was lost when the Payload Assist Modules (PAM) failed to boost them into usable orbit.
51-C (15) Discovery	Thomas K. Mattingly, C Loren J. Shriver, P James F. Buchli, MS Ellison S. Onizuka, MS Gary E. Payton, PS	OPF 35 days VAB 14 days Pad 20 days	Jan. 24, 1985 2:40 p.m. EST, Kennedy Space Center, Fla. First set for Jan. 23, but scrubbed due to freezing weather conditions. Orbiter Challenger was originally scheduled for mission, but thermal tile problems forced substitution of Discovery.	Jan. 27, 4:23 P.M. EST, Runway 15, Kennedy Space Center. Mission duration 3 days, one hour, 33 minutes.	Space Shuttle Discovery's third trip to space. First mission totally dedicated to the Department of Defense. The U.S. Air Force Inertial Upper Stage (IUS) booster rocket was deployed and successfully met its mission objectives.

KSC Release No. 107-85

SPACE SHUTTLE MISSION SUMMARY – STS-1 thru 51-L

Key: (C) Commander (P) Pilot (MS) Mission Specialist (PS) Payload Specialist

FLIGHT	CREW	LAUNCH PREPS	LAUNCH	LANDING	MISSION
51-D(16) Discovery	Karol J. Bobko (C) Donald E. Williams (P) M. Rhea Seddon (MS) S. David Griggs (MS) Jeffrey A. Hoffman (MS) Chas. D. Walker (MS) Sen. E. J. "Jake" Garn (PS)	OPF 54 days VAB 5 days Pad 16 days	Liftoff from Pad A was at 8:59 a.m. EST April 12, 1985 with 55 seconds left in window due to weather problems.	Landing on KSC Runway 33 at 8:55 a.m. EST April 19. Rollout distance 10,500 ft. One right main gear tire had blowout. Landing was made on Orbit 110. Total MET 6 days, 23 hours, 55 minutes, 20 seconds. Distance traveled: 2 million miles.	Canadian Anik C-1 communications satellite was successfully deployed. Leasat 3 deployment from Discovery was successful but spacecraft sequencer failed to initiate antenna deployment, spin-up and ignite perigee kick motor. Mission extended two days to permit crew to make certain sequencer start lever was in proper position. Griggs and Hoffman performed EVA to attach "flyswatter" devices to RMS. MS Seddon engaged Leasat lever but post deployment sequence did not begin.
51-B(17) Challenger	Robert F. Overmyer (C) Frederick D. Gregory (P) Don L. Lind (MS) Norman E. Thagard (MS) William E. Thornton (MS) Lodewijk van den Berg (PS) Taylor G. Wang (PS)	OPF 33 days VAB 5 days Pad 15 days	Launched 12:02 p.m. EDT on April 29 from Pad A.	Landing made on 111th orbit at EAFB, Calif. 12:11 p.m. EDT May 6. MET: 7 days, 0 hours, 8 minutes. Rollout distance 8,317 feet.	First operational flight for European Space Agency developed laboratory. Of 15 experiments scheduled aboard Spacelab 3, 14 were successful. First time animals were flown with flight crew. Two monkeys and 24 rodents were observed during mission for effects of weightlessness. Mission's main objective was to provide high quality microgravity environment for delicate materials processing and fluid experiments. Traveled 2.89 million miles in 219-mile-high orbit inclined 57 degrees to the equator.
51-G(18) Discovery	Daniel Brandenstein (C) John Creighton (P) Shannon Lucid (MS) Steven Nagel (MS) John Fabian (MS) Patrick Baudry (PS) Sultan Al-Saud (PS)	OPF 38 days VAB 7 days Pad 14 days	Launched June 17, 1985 at 7:33 a.m. EDT. Launch from Complex 39-A on time and followed trouble-free countdown.	Landing was at EAFB, Calif. at 9:11:53 a.m. EDT June 24. MET: 7 days, 1 hour, 38 mins., 53 secs. Rollout distance: 8130 ft. Traveled 2.9 million miles. Landed on EAFB Runway 23 on Orbit 112.	Three communications satellite were successfully deployed: Morelos-1 (Mexico), Arabsat 1-B (Arab Satellite Communications Organization) and Telstar 3-D AT&T). Also flown were the deployable/retrievable Spartan 1, six Getaway Special canisters, an experiment for the Strategic Defense Initiative, a materials processing furnace and French biomedical experiments.
51-F(19) Challenger	Charles G. Fullerton (C) Roy D. Bridges (P) F. Story Musgrave (MS) Anthony W. England (MS) Karl G. Henize (MS) Loren W. Acton (PS) (Lockheed) John-David Bartoe (PS) (USN civilian)	OPF 43 days VAB 5 days Pad 14 days to abort Pad 17 days to launch	Launch attempt July 12 was halted at T–3 seconds due to malfunction of No. 2 engine coolant valve. All 3 engines were shut down. Launched at 5 p.m. EDT July 29. Abort To Orbit declared when No. 1 engine shut down early due to failed sensors.	Landed EAFB Aug. 6 at 3:45 p.m. EDT on 126th orbit. Mission Elapsed Time: 7 days, 22 hours, 45 minutes, 26 seconds.	Payload consisted of Spacelab-2 with igloo plus 3 pallets. The primary objective of the Spacelab-2 mission was to verify the performance of spacelab systems and determine the interface capability of the Space Shuttle orbiter, and to measure the environment induced by the spacecraft. Experiments covered the life sciences, plasma physics, astronomy, high-energy astrophysics, solar physics, atmospheric physics and technology research.
51-I(20) Discovery	Joe H. Engle (C) Richard O. Covey (P) James Van Hoften (MS) John M. Lounge (MS) William F. Fisher (MS)	OPF 30 days VAB 7 days Pad 22 days	Scheduled for launch 8:38 a.m. EDT Aug. 24. Launch was scrubbed at T–5 minutes due to cloud system in launch area. Aug. 25 launch attempt scrubbed at T–9 minutes due to failure of Discovery's No. 5 onboard computer (GPC). Launched at 6:58:01 a.m. EDT, Aug. 27 through hole in storm front.	Landing EAFB, Calif. at 9:16 a.m. EDT on Sept. 3. Mission Elapsed Time through wheel stop: 7 days, two hours, 18 minutes, 29 seconds. Landing on 112th orbit on EAFB Runway 23.	AUSSAT-1 and ASC-1 successfully deployed on Aug. 27. LEASAT-4 deployed on Aug. 29. Fisher and Van Hoften performed 7 hour, 1 minute, EVA on Aug. 31 and EVA of 4 hours, 26 minutes on Sept. 1 to repair and redeploy LEASAT-3 (which was first deployed from Discovery during the 51-D mission in April, 1985). (See 51-D mission chronology on Page 1 of this summary).
51-J(21) Atlantis	Karol Bobko (C) Ronald J. Grabe (P) Robert Stewart (MS) David Hilmers (MS) William A. Pailes (PS)	OPF 15 days* VAB 17 days Pad 34 days	First flight of orbiter Atlantis was launched at 11:15 a.m. EDT on Oct. 3.	Landing was made at EAFB, Calif. Runway 23 at 1:00 p.m. EDT Oct. 7. Rollout distance 8,056 feet. Flight duration 4 days, one hour, 45 minutes.	Department of Defense mission. Orbital parameters and other details of mission classified. First Atlantis mission highly successful.
61-A(22) Challenger	Henry W. Hartsfield (C) Steven R. Nagel (P) James F. Buchli (MS) Guion S. Bluford (MS) Bonnie J. Dunbar (MS) Reinhard Furrer (PS) Ernst Messerschmid (PS) Wubbo Ockels (PS)	OPF 61 days VAB 4 days Pad 15 days	Launched on Schedule at 12 noon EST Oct. 30, 1985. Countdown was uneventful and ascent to orbit nominal.	Landed EAFB, Calif., at 12:44:51 p.m. EST Nov. 6. MET: 7 days, 44 mins, 51 seconds. Rollout on Runway 17 was 8,304 feet.	The first dedicated German Spacelab mission was successfully conducted from 201-statute mile orbit inclined 57 degrees to the equator. Eight-member crew largest to date. Configuration was a long module equipped with vestibular sled. Mission highlights included basic and applied micro gravity research in the fields of materials science, life sciences and technology, and communications and navigation. Orbiter controlled from Johnson Space Center with scientific operations controlled from German Space Operations Center at Oberpfaffenhofen, near Munich.
61-B(23) Atlantis	Brewster H. Shaw Jr. (C) Bryan D. O'Connor (P) Mary L. Cleave (MS) Sherwood C. Spring (MS) Jerry L. Ross (MS) Rodolfo Neri Vela (PS) Charles Walker (PS)	OPF 27 days VAB 4 days Pad 14 days	Launched on schedule at 7:29 p.m. EST Nov. 26, 1985. The countdown was without incident and orbiter ascent was nominal. This was the second night launch of the Space Shuttle.	Landing was at 4:33 p.m. EST on Dec. 3 on Runway 22 at EAFB, Calif. Mission Elapsed Time: 6 days, 21 hours, 4 minutes, 50 seconds.	Three communications satellites were successfully deployed. These included Morelos-B (Mexico), AUSSAT 2 (Australian) and Satcom Ku 2 (RCA Americom). Other significant activity included the conduct of two experiments to test the feasibility of assembling erectable structures in space. These experiments were EASE (Experimental Assembly of Structures in Extravehicular Activity) and ACCESS (Assembly Concept for Construction of Erectable Space Structures). These required two EVAs by Mission Specialists Ross and Spring. EVAs lasted 5 hours, 32 minutes and 6 hours, 38 minutes. The McDonnell Douglas Continuous Flow Electrophoresis System (CFES) was flown for the third time and operated by PS Walker. PS Neri was the first Mexican national to be flown in space. Orbital altitude 218 to 235 statute miles with inclination of 28.5 degrees.

* – Note: Atlantis underwent two prior processing flows in OPF from April 14 to May 10 and May 28 to July 18 prior to beginning final 51-J processing flow on July 30. Interim periods were spent in Vehicle Assembly Building.

SPACE SHUTTLE MISSION SUMMARY – STS1 thru 51-L

Key: (C) Commander (P) Pilot (MS) Mission Specialist (PS) Payload Specialist

FLIGHT	CREW	LAUNCH PREPS	LAUNCH	LANDING.	MISSION
61-C(24) Columbia	Robert L. Gibson (C) Charles F. Bolden Jr. (P) Franklin Chang-Diaz (MS) Steven A. Hawley (MS) George D. Nelson (MS) Robert Cenker (PS) Cong. Bill Nelson (PS)	OPF 108 days VAB 10 days Pad 35 days	Scheduled for launch 7 a.m. Dec. 18. Delayed to Dec. 19 due to time needed to close out aft compartment. Weather pushed liftoff time to 7:54 a.m. GLS halted count at T–14 seconds due to out-of-tolerance turbine reading on right SRB HPU. Mission rescheduled for launch Jan. 6. Launch attempt Jan. 6 halted at T–31 seconds due to problem with lox fill and drain valve and end of window. Launch attempt on Jan. 7 halted at T–9 minutes. Count remained in hold while launch team waited for weather at Dakar and Moron TAL sites to clear. KSC RTLS weather conditions also marginal. Launch rescheduled for Jan. 9. Launch rescheduled for Jan. 10 to permit removal of an obstruction in the SSME No. 2 lox prevalve. On Jan. 10, launch attempt was abandoned at 8:44 a.m. due to heavy rains in pad area. Launch rescheduled for Jan. 12. Launched Jan. 12 at 6:55 a.m. EST.	Landing attempt on Jan. 16 waved off due to unfavorable weather. On Jan. 17 unfavorable weather forced another wave off. Mission extended by one day to provide KSC landing opportunity on Jan. 18 and avoid time lost in an Edwards AFB landing and turnaround. Landed at EAFB at 8:59 a.m. EST Jan. 18 after weather wave-off at KSC. MET: 6 days, 2 hours, 4 minutes, nine seconds.	RCA Satcom KU-1 successfully deployed. CHAMP experiment did not function properly due to battery problems. Decision made to shorten mission by one day to provide additional Columbia processing time for 61-E flight.
51-L(25) Challenger Pad B*	Francis R. Scobee (C) Michael J. Smith (P) Judith A. Resnik (MS) Ellison Onizuka (MS) Ronald E. McNair (MS) Christa McAuliffe (TISP) Gregory Jarvis (PS)	OPF 35 days VAB 8 days Pad 37 days	Jan. 22 launch date slipped to Jan. 23 and Jan. 24 to avoid conflict with 61-C. To Jan. 25 to meet close-out requirements. To Jan. 26 to accommodate Casablanca TAL option. To Jan. 27 due to unfavorable weather forecast for Jan. 26. Jan. 27 launch attempt scrubbed due to unacceptable crosswinds for RTLS at KSC SLF. Launched 11:38 a.m. EST Jan. 28. Explosion 1 minute, 13 seconds after liftoff claimed crew and vehicle.		The objectives of this mission included the deployment of Tracking and Data Relay Satellite-B (TDRS-B) and the flying of the Spartan-Halley's Comet experiment. SPARTAN was to have been deployed from Challenger's payload bay to bring two ultraviolet spectrographs to bear on the coma and tail of Halley's Comet. This mission also included the flying of the Teacher In Space Project.

*This was first Space Shuttle launch from Complex 39-B. All prior Shuttle flights were launched from Pad A

*** ELV PAYLOAD FLIGHT ASSIGNMENTS ***
OCTOBER 1987 MANIFEST

DATE YR MO	CLASS	LAUNCH VEHICLE TYPE	INCL	PAYLOAD ORBIT	LAUNCH SITE	PAYLOAD
88 01	MEDIUM	DELTA 181	28.6	LEO	ESMC	DOD-2
88 02 *	MEDIUM	ATLAS 63I	98.7	SS	WSMC	NOAA-H
88 03	SMALL	SCOUT S-206C	2.9	LEO	SMR	SAN MARCO-DL
88 05	SMALL	SCOUT S-212C	37.0	LEO	WFF	ITV-2
88 08	MEDIUM	DELTA 183	43.0	LEO	ESMC	DOD-3
88 08	SMALL	SCOUT S-213C	90.0	LEO	WSMC	SOOS-3
88 10 *	INTERMEDIATE	ATLAS CENTAUR 68	28.5	GSO	ESMC	FLTSATCOM-F8
89 02	MEDIUM	DELTA 184	99.0	SS	WSMC	COBE
89 02	SMALL	SCOUT S-214C	90.0	LEO	WSMC	SOOS-4
89 03	MEDIUM	ATLAS 50E	98.7	SS	WSMC	NOAA-D
89 05	SMALL	SCOUT S-215C	37.0	LEO	WFF	ITV-3
89 08	SMALL	SCOUT S-210C	90.0	LEO	WSMC	NOVA-II
90 02	MEDIUM	DELTA	57.0	LEO	ESMC	ROSAT
90 02	SMALL	SCOUT S-218C	90.0	LEO	WSMC	TRANSIT-27

* NOT BEFORE THIS DATE
** FOR NASA PLANNING PURPOSES

*** ELV PAYLOAD FLIGHT ASSIGNMENTS ***
OCTOBER 1987 MANIFEST

DATE YR MO	CLASS	LAUNCH VEHICLE TYPE	INCL	PAYLOAD ORBIT	LAUNCH SITE	PAYLOAD
90 03	INTERMEDIATE	ATLAS CENTAUR	28.5	GSO	ESMC	GOES-I
90 05	SMALL	SCOUT S-216C	37.0	LEO	WFF	ITV-4
90 06	INTERMEDIATE	ATLAS CENTAUR **	TBD	GTO	ESMC	CRRES
90 06	MEDIUM	ATLAS 34E	98.7	SS	WSMC	NOAA-I
90 08	SMALL	SCOUT S-211C	90.0	LEO	WSMC	TRANSIT-2R
90 12	INTERMEDIATE	ATLAS CENTAUR	28.5	GSO	ESMC	GOES-J
91 05 *	LARGE	TITAN IV **/IUS	28.5	EO	ESMC	PLANETARY B/U
91 05	SMALL	SCOUT S-217C	37.0	LEO	WFF	ITV-5
91 06	SMALL	TBD **	TBD	LEO	TBD	NASA-1 **
91 08 *	INTERMEDIATE	TITAN III **/IUS	28.5	GSO	ESMC	TDRS-F
91 08	MEDIUM	DELTA	28.5	LEO	ESMC	EUVE
91 09	MEDIUM	ATLAS 45E	98.7	SS	WSMC	NOAA-J
91 09	SMALL	TBD **	TBD	LEO	TBD	NASA-2 **

* NOT BEFORE THIS DATE
** FOR NASA PLANNING PURPOSES

*** ELV PAYLOAD FLIGHT ASSIGNMENTS ***
OCTOBER 1987 MANIFEST

DATE YR MO	CLASS	LAUNCH VEHICLE TYPE	INCL	PAYLOAD ORBIT	LAUNCH SITE	PAYLOAD
92 01	SMALL	TBD **	TBD	LEO	TBD	NASA-3 **
92 05	INTERMEDIATE	ATLAS CENTAUR	28.5	GSO	ESMC	GOES-K
92 06	MEDIUM	TBD **	28.7	HE	ESMC	WIND
92 06	SMALL	TBD **	TBD	LEO	TBD	NASA-4 **
92 07	MEDIUM	TBD **	TBD	HE	ESMC	GEOTAIL
92 08 *	INTERMEDIATE	TBD **	TBD	TBD	ESMC	MO/TDRS BACKUP
92 12	MEDIUM	TBD **	90.0	LEO	WSMC	POLAR
92 12	MEDIUM	TBD	98.7	SS	WSMC	NOAA-K
93 01	SMALL	TBD **	TBD	LEO	TBD	NASA-5 **
93 02	LARGE	TITAN IV /CENTAUR **	33.0	EO	ESMC	CRAF **
93 03	MEDIUM	TBD **	28.7	HE	ESMC	ESP-CLUSTER
93 03	INTERMEDIATE	TBD **	TBD	EO	ESMC	LUNAR OBSERVER **
93 03	MEDIUM	TBD **	28.7	GSO	ESMC	MSAT **
93 06	SMALL	TBD **	TBD	LEO	TBD	NASA-6 **

* NOT BEFORE THIS DATE
** FOR NASA PLANNING PURPOSES

*** ELV PAYLOAD FLIGHT ASSIGNMENTS ***
OCTOBER 1987 MANIFEST

DATE YR MO	CLASS	LAUNCH VEHICLE TYPE	INCL	PAYLOAD ORBIT	LAUNCH SITE	PAYLOAD
94 01	SMALL	TBD **	TBD	LEO	TBD	NASA-7 **
94 03	MEDIUM	TBD	98.7	SS	WSMC	NOAA-L
94 06	LARGE	TITAN IV **	98.6	LEO	WSMC	RADARSAT **
94 06	SMALL	TBD **	TBD	LEO	TBD	NASA-8 **
95 01	SMALL	TBD **	TBD	LEO	TBD	NASA-9 **
95 06	MEDIUM	TBD	98.7	SS	WSMC	NOAA-M
95 06	SMALL	TBD **	TBD	LEO	TBD	NASA-10 **
95 12	MEDIUM	TBD **	28.5	LEO	ESMC	COLD-SAT **

* NOT BEFORE THIS DATE
** FOR NASA PLANNING PURPOSES

KSC Historical Report No. 1A (KHR-1A)

MAJOR NASA LAUNCHES

(EXCLUDING SPACE SHUTTLE LAUNCHES AND PAYLOADS;
SEE KHR-1B FOR SHUTTLE DATA)
EASTERN TEST RANGE (ETR) AND WESTERN TEST RANGE (WTR)
OCTOBER 1, 1958 - DECEMBER 31, 1986
TOTAL MAJOR ETR AND WTR LAUNCHES 333

MAJOR NASA LAUNCHES ARE FROM THE KENNEDY SPACE CENTER AND CAPE CANAVERAL AIR FORCE STATION (EASTERN TEST RANGE) IN FLORIDA; THEY INCLUDE LAUNCHES AT THE VANDENBERG AIR FORCE BASE (WESTERN TEST RANGE) IN CALIFORNIA. LAUNCHES OF NON-MILITARY SPACECRAFT BY THE U.S. AIR FORCE AT VANDENBERG AIR FORCE BASE AND LAUNCHES OF THE SMALLER NASA SCOUT VEHICLE ARE NOT LISTED ON THIS CHART.

NOTES:

RESULTS:

S – Successful
P – Launch Successful – Mission Failure
U – Unsuccessful

1 – Multiple payload aboard single launch vehicle
2 – Launched from Western Test Range (WTR)
3 – Thrust-augmented first stage (solid motor strap-ons)
4 – NASA Launch – non-NASA mission or joint project
5 – BP: Boilerplate, or dummy; S/C: Spacecraft;
CSM: Apollo command and service modules; LM: Apollo lunar module; DM: docking module
6 – Planned as first manned Apollo mission – – – failed in ground test 1/27/67
7 – See KHR–1B for spacecraft in this series launched on the Space Shuttle

National Aeronautics and
Space Administration

EARTH OBSERVATIONS

METEOROLOGY

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
TIROS (Television Infrared Observations Satellites)						
TIROS 1	4/1/60	Thor-Able 5	A-1	17A	315	S
TIROS 2	11/23/60	Delta-3	TIROS-B (A-2)	17A	3804	S
TIROS 3	7/12/61	Delta-5	TIROS-C (A-3)	17A	1351	S
TIROS 4	2/8/62	Delta-7	TIROS-D (A-9)	17A	123	S
TIROS 5	6/19/62	Delta-10	TIROS-E (A-50)	17A	820	S
TIROS 6	9/18/62	Delta-12	TIROS-F (A-51)	17A	5046	S
TIROS 7	6/19/63	Delta 19	TIROS-G (A-52)	17B	115	S
TIROS 8	12/21/63	Delta-22	TIROS-H (A-53)	17B	5332	S
TIROS 9	1/22/65	Delta-28	TIROS-I (A-54)	17A	285	S
TIROS OPERATIONAL						
[4]TIROS 10	7/1/65	Delta-32	OT 1	17B	2756	S
[4]ESSA 1	2/3/66	Delta-36	OT 3 (TOS)	17A	200	S
[4]ESSA 2	2/28/66	[3]Delta-37	OT-2 (TOS)	17B	405	S
[4]ESSA 3	10/2/66	[3]Delta-41	TOS-A	[2]SLC-2E		S
[4]ESSA 4	1/26/67	[3]Delta-45	TOS-B	[2]SLC-2E		S
[4]ESSA 5	4/20/67	[3]Delta-48	TOS-C	[2]SLC-2E		S
[4]ESSA 6	11/10/67	[3]Delta-54	TOS-D	[2]SLC-2E		S
[4]ESSA 7	8/16/68	[3]Delta-58	TOS-E	[2]SLC-2E		S
[4]ESSA 8	12/15/68	[3]Delta-62	TOS-F	[2]SLC-2E		S
[4]ESSA 9	2/26/69	[3]Delta-67	TOS-G	17B	3163	S
IMPROVED TIROS OPERATIONAL						
[4]ITOS 1/OSCAR 5	1/23/70	[3]Delta-76	[1]TIROS M/OSCAR	[2]SLC-2W		S
[4]NOAA 1	12/11/70	[3]Delta-81	ITOS-A	[2]SLC-2W		S
[4]ITOS	10/21/71	[3]Delta-86	ITOS-B	[2]SLC-2E		U
[4]NOAA 2/OSCAR 6	10/15/72	[3]Delta-91	[1]ITOS-D/OSCAR	[2]SLC-2W		S
[4]ITOS	7/16/73	[3]Delta-96	ITOS-E	[2]SLC-2W		U
[4]NOAA 3	11/6/73	[3]Delta-98	ITOS-F	[2]SLC-2W		S
[4]NOAA 4/INTASAT/ OSCAR 7	11/15/74	[3]Delta-104	[1]ITOS-G/INTASAT/ OSCAR	[2]SLC-2W		S
[4]NOAA 5	7/29/76	[3]Delta-126	ITOS-E 2	[2]SLC-2W		S
NIMBUS						
Nimbus 1	8/28/64	Thor-Agena-3	Nimbus-A	[2]SLC-2E		S
Nimbus 2	5/15/66	[3]Thor-Agena-6	Nimbus-C	[2]SLC-2E		S
Nimbus	5/18/68	[3]Thor-Agena-9	Nimbus-B	[2]SLC-2E		U
Nimbus 3/SECOR	4/13/69	[3]Thor-Agena-10	[1]Nimbus-B2/SECOR	[2]SLC-2E		S
Nimbus 4/TOPO 1	4/8/70	[3]Thor-Agena-13	[1]Nimbus-D/TOPO	[2]SLC-2E		S
Nimbus 5	12/10/72	[3]Delta-93	Nimbus-E	[2]SLC-2W		S
Nimbus 6	6/12/75	[3]Delta-111	Nimbus-F	[2]SLC-2W		S
Nimbus 7	10/24/78	[3]Delta-145	Nimbus-G	[2]SLC-2W		S
GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES						
[4]SMS 1	5/17/74	[3]Delta 102	SMS-A	17B	3938	S
[4]SMS 2	2/6/75	[3]Delta 108	SMS-B	17B	4763	S
[4]GOES 1	10/16/75	[3]Delta 116	GOES-A	17B	2977	S
[4]GOES 2	6/16/77	[3]Delta 131	GOES-B	17B	1967	S
[4]GOES 3	6/16/78	[3]Delta 142	GOES-C	17B	4550	S
[4]GOES 4	9/9/80	[3]Delta 152	GOES-D	17A	4642	S
[4]GOES 5	5/22/81	[3]Delta 154	GOES-E	17A	8976	S
[4]GOES 6	4/28/83	[3]Delta 168	GOES-F	17A	7310	S
[4]GOES G	5/3/86	[3]Delta 178	GOES-G	17A	4976	U
INTERNATIONAL GEOSTATIONARY METEOROLOGICAL SATELLITES						
[4]GMS (Japan)	7/14/77	[3]Delta-132	GMS	17B	6245	S
[4]METEOSAT (ESA)	11/22/77	[3]Delta-136	METEOSAT	17A	0450	S

GEODESY

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
GEOS (Geodetic Satellites)						
GEOS 1 (Explorer 29)	11/6/65	[3]Delta-34	GEOS-A	17A	1400	S
PAGEOS 1	6/23/66	[3]Thor-Agena-7	PAGEOS-A	[2]SLC-2E		S
GEOS 2 (Explorer 36)	1/11/68	[3]Delta-56	GEOS-B	[2]SLC-2E		S
GEOS 3	4/9/75	[3]Delta-109	GEOS-C	[2]SLC-2W		S
LAGEOS (Laser Geodynamic Satellites)						
LAGEOS 1	5/4/76	[3]Delta-123	LAGEOS	[2]SLC-2W		S

EARTH RESOURCES TECHNOLOGY

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
ERTS (Earth Resources Technology Satellites)						
LANDSAT 1	7/23/72	[3]Delta-89	ERTS-A	[2]SLC-2W		S
LANDSAT 2	1/22/75	[3]Delta-107	ERTS-B	[2]SLC-2W		S
LANDSAT 3/OSCAR 8	3/5/78	[3]Delta-139	[1]LANDSAT-C/ OSCAR	[2]SLC-2W		S
LANDSAT 4	7/16/82	[3]Delta-163	Landsat-D	[2]SLC-2W		S
[4]LANDSAT 5	3/1/84	[3]Delta-174	Landsat D Prime	[2]SLC-2W		S

APPLICATIONS TECHNOLOGY

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
ATS (Applications Technology Satellites)						
ATS 1	12/6/66	Atlas-Agena-19	ATS-B	12	8287	S
ATS 2	4/5/67	Atlas-Agena-21	ATS-A	12	4570	P
ATS 3	11/5/67	Atlas-Agena-25	ATS-C	12	2900	S
ATS 4	8/10/68	Atlas-Centaur-17	ATS-D	36A	4089	P
ATS 5	8/12/69	Atlas-Centaur-18	ATS-E	36A	1711	S
ATS 6	5/30/74	Titan III-C	ATS-F	40	7670	S
STRATEGIC DEFENSE INITIATIVE						
[4]SDI-1	9/5/86	Delta 180	SDI-1	17B	5200	S

MANNED SPACE FLIGHT

MERCURY

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
SUBORBITAL						
Big Joe	9/9/59	Atlas-10D	[5]BP S/C	14	2119	S
MA-1	7/29/60	Mercury-Atlas-50D	[5]S/C-4	14	1505	U
MR-1	11/21/60	Mercury-Redstone-1	[5]S/C-2	5	4500	U
MR-1A	12/19/60	Mercury-Redstone-3	[5]S/C 2A	5	5111	S
MR-2 (Chimp "Ham")	1/31/61	Mercury-Redstone-2	[5]S/C-5	5	3805	S
MA-2	2/21/61	Mercury-Atlas-67D	[5]S/C-6	14	419	S
MR-BD	3/24/61	Mercury-Redstone-5	[5]BP S/C	5	1375	S
MR-3 (Shepard)	5/5/61	Mercury-Redstone-7	Freedom 7	5	108	S
MR-4 (Grissom)	7/21/61	Mercury-Redstone-8	Liberty Bell 7	5	1809	S
ORBITAL						
MA-3	4/25/61	Mercury-Atlas-100D	[5]S/C-8	14	835	U
MA-4	9/13/61	Mercury-Atlas-88D	[5]S/C-8A	14	1254	S
MS-1	11/1/61	Mercury-Scout	–	18B	3753	U
MA-5 (Chimp "Enos")	11/29/61	Mercury-Atlas-93D	[5]S/C-9	14	1810	S
MA-6 (Glenn)	2/20/62	Mercury-Atlas-109D	Friendship 7	14	5460	S
MA-7 (Carpenter)	5/24/62	Mercury-Atlas-107D	Aurora 7	14	65	S
MA-8 (Schirra)	10/3/62	Mercury-Atlas-113D	Sigma 7	14	66	S
MA-9 (Cooper)	5/15/63	Mercury-Atlas-130D	Faith 7	14	125	S

GEMINI

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
SUBORBITAL						
Gemini 2	1/19/65	Titan II GLV-2	[5]Gemini S/C-2	19	4466	S
ORBITAL						
Gemini 1	4/8/64	Titan II GLV-1	[5]Gemini S/C-1	19	275	S
Gemini 3 (Grissom-Young)	3/23/65	Titan II GLV-3	[5]Gemini S/C-3	19	475	S
Gemini 4 (McDivitt-White)	6/3/65	Titan II GLV-4	[5]Gemini S/C-4	19	1777	S
Gemini 5 (Cooper-Conrad)	8/21/65	Titan II GLV-5	[5]Gemini S/C-5	19	2315	S
Gemini 6 Target Vehicle	10/25/65	Atlas TLV 5301	Agena TV 5002	14	4994	U
Gemini 7 (Borman-Lovell)	12/4/65	Titan II GLV-7	[5]Gemini S/C-7	19	6145	S
Gemini 6A (Schirra-Stafford)	12/15/65	Titan II GLV-6	[5]Gemini S/C-6	19	7100	S
Gemini 8 Target Vehicle	3/16/66	Atlas TLV 5302	Agena TV 5003	14	2166	P
Gemini 8 (Armstrong-Scott)	3/16/66	Titan II GLV-8	[5]Gemini S/C-8	19	1503	P
Gemini 9 Target Vehicle	5/17/66	Atlas TLV 5303	Agena TV 5004	14	2398	U
Gemini 9A Augmented Target	6/1/66	Atlas TLV 5304	ATDA	14	5060	P
Gemini 9A (Stafford-Cernan)	6/3/66	Titan II GLV-9	[5]Gemini S/C-9	19	2433	P
Gemini 10 Target Vehicle	7/18/66	Atlas TLV 5305	Agena TV 5005	14	5434	S
Gemini 10 (Young-Collins)	7/18/66	Titan II GLV-10	[5]Gemini S/C-10	19	6833	S
Gemini 11 Target Vehicle	9/12/66	Atlas TLV 5306	Agena TV 5006	14	2429	S
Gemini 11 (Conrad-Gordon)	9/12/66	Titan II GLV-11	[5]Gemini S/C-11	19	3287	S
Gemini 12 Target Vehicle	11/11/66	Atlas TLV 5307	Agena TV 5001	14	3678	S
Gemini 12 (Lovell-Aldrin)	11/11/66	Titan II GLV-12	[5]Gemini S/C-12	19	2742	S

APOLLO

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
MSFN TEST & TRAINING SATELLITES						
TTS 1/Pioneer 8	12/13/67	[3]Delta-55	[1]TTS-A	17B	2898	S
TETR 2/Pioneer 9	11/8/68	[3]Delta-60	[1]TETR-B	17B	6850	S
TETR/Pioneer	8/27/69	[3]Delta-73	[1]TETR-C	17A	2052	U
TETR 3/OSO 7	9/29/71	[3]Delta-85	[1]TETR-D	17A	4617	S
SUBORBITAL						
Apollo-Saturn	2/26/66	Saturn IB AS-201	[5]CSM-009	34	195	S
Apollo-Saturn	8/25/66	Saturn IB AS-202	[5]CSM-011	34	7897	S
EARTH ORBITAL						
Saturn-Apollo	5/28/64	Saturn I SA-6	[5]CSM BP-13	37B	2769	S
Saturn-Apollo	9/18/64	Saturn I SA-7	[5]CSM BP-15	37B	4444	S
Saturn-Apollo (Pegasus 1)	2/16/65	Saturn I SA-9	[5]CSM BP-16	37B	143	S
Saturn-Apollo (Pegasus 2)	5/25/65	Saturn I SA-8	[5]CSM BP-26	37B	2222	S
Saturn-Apollo (Pegasus 3)	7/30/65	Saturn I SA-10	[5]CSM BP-9A	37B	3530	S
[6]Apollo 1 (Grissom, White, Chaffee)		Saturn IB AS-204	[5]CSM-012	34		
Apollo 4	11/9/67	Saturn V AS-501	[5]CSM-017	39A	72	S
Apollo 5	1/22/68	Saturn IB AS-204	[5]LM-1	37B	2320	S
Apollo 6	4/4/68	Saturn V AS-502	[5]CSM-020	39A	6343	P
Apollo 7 (Schirra, Eisele, Cunningham)	10/11/68	Saturn IB AS-205	[5]CSM-101	34	66	S
Apollo 9 (McDivitt, Scott, Schweickart)	3/3/69	Saturn V AS-504	[5]CSM-104, LM-3	39A	9025	S
LUNAR ORBITAL						
Apollo 8 (Borman, Lovell, Anders)	12/21/68	Saturn V AS-503	[5]CSM-103	39A	170	S
Apollo 10 (Stafford, Young, Cernan)	5/18/69	Saturn V AS-505	[5]CSM-106, LM-4	39B	920	S
LUNAR LANDING						
Apollo 11 (Armstrong, Collins, Aldrin)	7/16/69	Saturn V AS-506	[5]CSM-107, LM-5	39A	5307	S
Apollo 12 (Conrad, Gordon, Bean)	11/14/69	Saturn V AS-507	[5]CSM-108, LM-6	39A	2793	S
Apollo 13 (Lovell, Swigert, Haise)	4/11/70	Saturn V AS-508	[5]CSM-109, LM-7	39A	3381	P
Apollo 14 (Shepard, Roosa, Mitchell)	1/31/71	Saturn V AS-509	[5]CSM-110, LM-8	39A	7194	S
Apollo 15 (Scott, Worden, Irwin)	7/26/71	Saturn V AS-510	[5]CSM-112, LM-10	39A	7744	S
Apollo 16 (Young, Mattingly, Duke)	4/16/72	Saturn V AS-511	[5]CSM-113, LM-11	39A	1601	S
Apollo 17 (Cernan, Evans, Schmitt)	12/7/72	Saturn V AS-512	[5]CSM-114, LM-12	39A	1701	S

SKYLAB

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
SKYLAB						
Skylab 1	5/14/73	Saturn V AS-513	Orbital Workshop	39A	6707	S
Skylab 2 (Conrad, Weitz, Kerwin)	5/25/73	Saturn IB AS-206	[5]CSM-116	39B	5914	S
Skylab 3 (Bean, Garriott, Lousma)	7/28/73	Saturn IB AS-207	[5]CSM-117	39B	4458	S
Skylab 4 (Carr, Pogue, Gibson)	11/16/73	Saturn IB AS-208	[5]CSM-119	39B	7729	S

INTERNATIONAL SPACE SCIENCE

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
AERIEL (British)						
Aeriel 1	4/26/62	Delta-9	S-51 (UK-1)	17A	83	S
ALOUETTE (Canadian)						
Alouette 1	9/29/62	Thor-Agena-1	S-27	[2]SLC-2E		S
Alouette 2/Explorer 31	11/28/65	Thor-Agena-5	[1]Alouette-B/DME-A	[2]SLC-2E		S
ISIS (Canadian)						
ISIS 1	1/28/69	[3]Delta-65	ISIS-A	[2]SLC-2E		S
ISIS 2	3/31/71	[3]Delta-84	ISIS-B	[2]SLC-2E		S
ESA (European Space Agency, Formerly ESRO)						
[4]HEOS 1	12/5/68	[3]Delta-61	HEOS-A	17B	8560	S
[4]HEOS 2	1/31/72	[3]Delta-87	HEOS-A2	[2]SLC-2E		S
[4]TD 1	3/11/72	[3]Delta-88	TD-1/A	[2]SLC-2E		S
[4]Cosmic 1	8/8/75	[3]Delta-113	COS-B	[2]SLC-2W		S
[4]Geos	4/20/77	[3]Delta-130	ESRO/Geos	17B	0747	P
[4]Geos 2	7/14/78	[3]Delta-143	Geos-2	17A	5544	S
INTASAT (Spanish)						
[4]INTASAT/NOAA 4/ OSCAR 7	11/15/74	[3]Delta-104	[1]INSAT/ITOS /OSCAR	[2]SLC-2W		S
HELIOS (German)						
[4]Helios 1	12/10/74	Titan III-Centaur-2	Helios-A	41	3718	S
[4]Helios 2	1/15/76	Titan III-Centaur-5	Helios-B	41	2675	S
IRAS (Infrared Astronomical Satellite)						
[4]IRAS	1/25/83	[3]Delta-166	IRAS	[2]SLC-2W	9405	S
EXOSAT						
[4]Exosat	5/26/83	[3]Delta-169	Exosat	[2]SLC-2W	4150	S
ACTIVE MAGNETOSPHERIC PARTICLE TRACER EXPLORERS						
[4]AMPTE	8/16/84	[3]Delta-175	[1]AMPTE	17A	5125	S

BIOSCIENCE

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE*	LAUNCH PAD	ETR TEST NO.	RESULTS
BIOFLIGHTS (Suborbital Primate Flights)						
BIOFLIGHT 1	12/13/58	Jupiter AM-13	Gordo	26B	2906	P
BIOFLIGHT 2	5/28/59	Jupiter AM-18	Able-Baker	26B	1751	S
BIOS (Biological Satellites)						
BIOS 1	12/14/66	[3]Delta-43	BIOS-A	17A	7060	P
BIOS 2	9/7/67	[3]Delta-51	BIOS-B	17B	4447	S
BIOS 3	6/28/69	[3]Delta-70	BIOS-D	17A	197	P

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
PIONEER (Lunar)						
Pioneer 1	10/11/58	Thor-Able-1	–	17A	1863	U
Pioneer 2	11/8/58	Thor-Able-2	–	17A	1806	U
Pioneer 3	12/6/58	Juno II AM-11	–	5	2907	U
Pioneer 4	3/3/59	Juno II AM-14	–	5	250	S
Pioneer	11/26/59	Atlas-Able-1	–	14	4122	U
Pioneer	9/25/60	Atlas-Able-2	P-30	12	2801	U
Pioneer	12/15/60	Atlas-Able-3	P-31	12	4508	U
PIONEER (Interplanetary)						
Pioneer 5	3/11/60	Thor-Able-4	P-2	17A	43	S
Pioneer 6	12/16/65	[3]Delta-35	Pioneer-A	17A	4867	S
Pioneer 7	8/17/66	[3]Delta-40	Pioneer-B	17A	3633	S
Pioneer 8/TTS 1	12/13/67	[3]Delta-55	[1]Pioneer-C	17B	2898	S
Pioneer 9/TETR 2	11/8/68	[3]Delta-60	[1]Pioneer-D	17B	6850	S
Pioneer/TETR	8/27/69	[3]Delta-73	[1]Pioneer-E	17A	2052	U
Pioneer 10	3/2/72	Atlas-Centaur-27	Pioneer-F	36A	2104	S
Pioneer 11	4/5/73	Atlas-Centaur-30	Pioneer-G	36B	8088	S
Pioneer Venus 1	5/20/78	Atlas-Centaur-50	Pioneer Venus Orbiter	36A	2440	S
Pioneer Venus 2	8/8/78	Atlas-Centaur-51	Pioneer Venus Multiprobe	36A	7450	S
RANGER						
Ranger 1	8/23/61	Atlas-Agena-1	P-32	12	5050	U
Ranger 2	11/18/61	Atlas-Agena-2	P-33	12	4507	U
Ranger 3	1/26/62	Atlas-Agena-3	P-34	12	125	U
Ranger 4	4/23/62	Atlas-Agena-4	P-35	12	821	P
Ranger 5	10/18/62	Atlas-Agena-7	P-36	12	5050	P
Ranger 6	1/30/64	Atlas-Agena-8	Ranger-A (P-53)	12	250	P
Ranger 7	7/28/64	Atlas-Agena-9	Ranger-B (P-54)	12	448	S
Ranger 8	2/17/65	Atlas-Agena-13	Ranger-C	12	235	S
Ranger 9	3/21/65	Atlas-Agena-14	Ranger-D	12	300	S
SURVEYOR						
Surveyor 1	5/30/66	Atlas-Centaur-10	Surveyor-A	36A	184	S
Surveyor 2	9/20/66	Atlas-Centaur-7	Surveyor-B	36A	5739	P
Surveyor 3	4/17/67	Atlas-Centaur-12	Surveyor-C	36B	6950	S
Surveyor 4	7/14/67	Atlas-Centaur-11	Surveyor-D	36A	4213	P
Surveyor 5	9/8/67	Atlas-Centaur-13	Surveyor-E	36B	7213	S
Surveyor 6	11/7/67	Atlas-Centaur-14	Surveyor-F	36B	2020	S
Surveyor 7	1/7/68	Atlas-Centaur-15	Surveyor-G	36A	1384	S
LUNAR ORBITER						
Lunar Orbiter 1	8/10/66	Atlas-Agena-17	LO-A	13	4003	S
Lunar Orbiter 2	11/6/66	Atlas-Agena-18	LO-B	13	1469	S
Lunar Orbiter 3	2/4/67	Atlas-Agena-20	LO-C	13	3424	S
Lunar Orbiter 4	5/4/67	Atlas-Agena-22	LO-D	13	2935	S
Lunar Orbiter 5	8/1/67	Atlas-Agena-24	LO-E	13	6622	S
MARINER						
Mariner 1 (Venus)	7/22/62	Atlas-Agena-5	P-37	12	2500	U
Mariner 2 (Venus)	8/27/62	Atlas-Agena-6	P-38	12	3731	S
Mariner 3 (Mars)	11/5/64	Atlas-Agena-11	Mariner-64C	13	5800	U
Mariner 4 (Mars)	11/28/64	Atlas-Agena-12	Mariner-64D	12	5049	S
Mariner 5 (Venus)	6/14/67	Atlas-Agena-23	Mariner-67E	12	5102	S
Mariner 6 (Mars)	2/24/69	Atlas-Centaur-20	Mariner-69F	36B	183	S
Mariner 7 (Mars)	3/27/69	Atlas-Centaur-19	Mariner 69G	36A	6891	S
Mariner 8 (Mars)	5/8/71	Atlas-Centaur-24	Mariner-71H	36A	366	U
Mariner 9 (Mars)	5/30/71	Atlas-Centaur-23	Mariner-71I	36B	7744	S
Mariner 10 (Mercury)	11/3/73	Atlas-Centaur-34	Mariner-73J	36B	3369	S
VIKING						
Viking 1 (Mars)	8/20/75	Titan III Centaur-4	Viking-A	41	3396	S
Viking 2 (Mars)	9/9/75	Titan III-Centaur-3	Viking-B	41	3717	S
VOYAGER						
Voyager 2	8/20/77	Titan III-Centaur-7	Voyager-2	41	0808	S
Voyager 1	9/5/77	Titan III-Centaur-6	Voyager-1	41	0777	S

COMMUNICATIONS

TECHNOLOGY DEVELOPMENT

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
ECHO						
Echo	5/13/60	Delta-1	A-10	17A	618	U
Echo 1	8/12/60	Delta-2	A-11	17A	1506	S
Echo (Big Shot 1)	1/15/62	Thor-337	AVT-1 (A-12)	17A	6210	P
Echo (Big Shot 2)	7/18/62	Thor-338	AVT-2 (A-12)	17A	82	S
Echo 2	1/25/64	Thor-Agena-2	A-12	[2]SLC-2E		S
TELSTAR						
[4]Telstar 1	7/10/62	Delta-11	A-40	17B	1341	S
[4]Telstar 2	5/7/63	Delta-18	A-41	17B	1600	S
RELAY						
Relay 1	12/13/62	Delta-15	A-15	17A	3568	S
Relay 2	1/21/64	Delta-23	A-16	17B	475	S
SYNCOM						
Syncom 1	2/14/63	Delta-16	Syncom-A (A-25)	17B	136	P
Syncom 2 (Atlantic)	7/26/63	Delta-20	Syncom-B (A-26)	17A	3710	S
Syncom 3 (Pacific)	8/19/64	Delta-25	Syncom-C	17A	136	S
SYMPHONIE (French-German Experimental Communications Satellites)						
[4]Symphonie 1	12/18/74	[3]Delta-106	Symphonie-A	17B	3862	S
[4]Symphonie 2	8/26/75	[3]Delta-114	Symphonie-B	17A	5365	S
COMMUNICATIONS TECHNOLOGY SATELLITES						
CTS (U.S.-Canadian)	1/17/76	[3]Delta-119	CTS	17B	2516	S
[4]SIRIO (Italian)	8/25/77	[3]Delta-133	SIRIO	17B	5999	S
[4]OTS-1 (ESA)	9/13/77	[3]Delta-134	OTS	17A	4010	U
[4]CS (Japan)	12/14/77	[3]Delta-137	CS	17B	1555	S
[4]BSE (Japan)	4/7/78	[3]Delta-140	BSE	17B	4360	S
[4]OTS-2 (ESA)	5/11/78	[3]Delta-141	OTS-2	17A	4440	S

OPERATIONAL SYSTEMS

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO.	RESULTS
INTERNATIONAL TELECOMMUNICATIONS SATELLITE ORGANIZATION						
[4]Intelsat I (Early Bird)	4/6/65	[3]Delta-30	EB-A	17A	500	S
[4]Intelsat II (Lani Bird)	10/26/66	[3]Delta-42	F-1	17B	5123	P
[4]Intelsat II	1/11/67	[3]Delta-44	F-2	17B	7367	S
[4]Intelsat II	3/22/67	[3]Delta-47	F-3	17B	5191	S
[4]Intelsat II	9/27/67	[3]Delta-52	F-4	17B	6988	S
[4]Intelsat III	9/18/68	[3]Delta-59	III-A	17A	7970	U
[4]Intelsat III	12/18/68	[3]Delta-63	F-2	17A	1380	S
[4]Intelsat III	2/5/69	[3]Delta-66	F-3	17A	3320	S
[4]Intelsat III	5/21/69	[3]Delta-68	F-4	17A	4501	S
[4]Intelsat III	7/25/69	[3]Delta-71	III-E	17A	2400	U
[4]Intelsat III	1/14/70	[3]Delta-75	F-6	17A	8460	S
[4]Intelsat III	4/22/70	[3]Delta-78	F-7	17A	5423	S
[4]Intelsat III	7/23/70	[3]Delta-79	III-H	17A	1003	P
[4]Intelsat IV	1/25/71	Atlas-Centaur-25	F-2	36A	2222	S
[4]Intelsat IV	12/19/71	Atlas-Centaur-26	F-3	36A	1473	S
[4]Intelsat IV	1/22/72	Atlas-Centaur-28	F-4	36B	615	S
[4]Intelsat IV	6/13/72	Atlas-Centaur-29	F-5	36B	1240	S
[4]Intelsat IV	8/23/73	Atlas-Centaur-31	F-7	36A	3207	S
[4]Intelsat IV	11/21/74	Atlas-Centaur-32	F-8	36B	3650	S
[4]Intelsat IV	2/20/75	Atlas-Centaur-33	F-6	36A	3757	U
[4]Intelsat IV	5/22/75	Atlas-Centaur-35	F-1	36A	6103	S
[4]Intelsat IV-A	9/25/75	Atlas-Centaur-36	F-1	36B	3072	S
[4]Intelsat IV-A	1/29/76	Atlas-Centaur-37	F-2	36B	4740	S
[4]Intelsat IV-A	5/26/77	Atlas-Centaur-39	F-4	36A	1666	S
[4]Intelsat IV-A	9/29/77	Atlas-Centaur-43	F-5	36A	2050	U
[4]Intelsat IV-A	1/6/78	Atlas-Centaur-46	F-3	36B	3525	S
[4]Intelsat IV-A	3/31/78	Atlas-Centaur-48	F-6	36B	2469	S
[4]Intelsat V	12/6/80	Atlas-Centaur-54	F-2	36B	5550	S
[4]Intelsat V	5/23/81	Atlas-Centaur-56	F-1	36B	6592	S
[4]Intelsat V	12/15/81	Atlas-Centaur-55	F-3	36B	5674	S
[4]Intelsat V	3/4/82	Atlas-Centaur-58	F-4	36A	2014	S
[4]Intelsat V	9/28/82	Atlas-Centaur-60	F-5	36B	5252	S
[4]Intelsat V	5/19/83	Atlas-Centaur-61	F-6	36A	3167	S
[4]Intelsat V	6/9/84	Atlas-Centaur-62	—	36B	6315	U
[4]Intelsat V-A	3/19/85	Atlas-Centaur-63	F-10	36B	5467	S
[4]Intelsat V-A	6/29/85	Atlas-Centaur-64	F-11	36B	6805	S
[4]Intelsat V-A	9/26/85	Atlas-Centaur-65	F-12	36B	7662	S
WESTAR (U. S. Domestic Communications Satellites)						
[4]Westar 1	4/13/74	[3]Delta-101	Westar-A	17B	4417	S
[4]Westar 2	10/10/74	[3]Delta-103	Westar-B	17B	4957	S
[4]Westar 3	8/9/79	[3]Delta-149	Westar-C	17A	2292	S
[4]Westar IV	2/25/82	[3]Delta-160	Westar-D	17A	3687	S
[4]Westar V	6/8/82	[3]Delta-162	Westar-E	17A	4551	S
See Note 7						
RCA (U. S. Domestic Communications Satellites)						
[4]SATCOM 1	12/12/75	[3]Delta-118	SATCOM-A	17A	2719	S
[4]SATCOM 2	3/26/76	[3]Delta-121	SATCOM-B	17A	3788	S
[4]SATCOM 3	12/6/79	[3]Delta-150	SATCOM-C	17A	4555	P
[4]SATCOM 3R	11/19/81	[3]Delta-158	SATCOM-D	17A	8081	S
[4]SATCOM IV	1/15/82	[3]Delta-159	SATCOM-C	17A	4732	S
[4]SATCOM V	10/27/82	[3]Delta-165	SATCOM-E	17B	6568	S
[4]SATCOM 1R	4/11/83	[3]Delta-167	SATCOM 1R	17A	3037	S
[4]SATCOM 2R	9/8/83	[3]Delta-172	SATCOM 2R	17B	8036	S
See Note 7						

SPACE SCIENCE

PHYSICS AND ASTRONOMY

MISSION NAME	LAUNCH DATE	LAUNCH VEHICLE	PAYLOAD CODE	LAUNCH PAD	ETR TEST NO	RESULTS
BEACON						
Beacon	10/22/58	Juno I RS 49	–	5	1800	U
Beacon	8/14/59	Juno II AM 19B	–	26B	2342	U
VANGUARD						
Vanguard 2	2/17/59	Vanguard SLV-4	59 Alpha	18A	260	P
Vanguard	4/13/59	Vanguard SLV-5	–	18A	771	U
Vanguard	6/22/59	Vanguard SLV-6	–	18A	1008	U
Vanguard 3	9/18/59	Vanguard SLV-7	59 Eta	18A	2111	S
EXPLORER						
Explorer	7/16/59	Juno II AM-16	S-1	5	2000	U
Explorer 6	8/7/59	Thor-Able-3	S-2	17A	1005	S
Explorer 7	10/13/59	Juno II AM-19A	S-1a	5	3509	S
Explorer	3/23/60	Juno II AM-19C	S-46	26B	620	U
Explorer 8	11/3/60	Juno II AM-19D	S-30	26B	4504	S
Explorer	2/24/61	Juno II AM-19F	S-45	26B	5109	U
Explorer 10	3/25/61	Delta-4	P-14	17A	407	S
Explorer 11	4/27/61	Juno II AM-19E	S-15	26B	814	S
Explorer	5/24/61	Juno II AM-19G	S-45a	26B	1253	U
Explorer 12	8/15/61	Delta-6	S-3	17A	1811	S
Explorer 14	10/2/62	Delta-13	S-3a	17B	4244	S
Explorer 15	10/27/62	Delta-14	S-3b	17B	6146	S
Explorer 17	4/2/63	Delta-17	S-6	17A	510	S
Explorer 18	11/26/63	Delta-21	IMP-A (S-74)	17B	6900	S
Beacon-Explorer	3/19/64	Delta-24	BE-A (S 66)	17A	125	U
Explorer 21	10/3/64	Delta 26	IMP-B (S-74a)	17A	131	S
Explorer 26	12/21/64	Delta-27	EPE-D (S-3c)	17A	2873	S
Explorer 28	5/29/65	Delta-31	IMP-C (S-74b)	17B	1922	S
Explorer 31/Alouette 2	11/28/65	Thor-Agena-5	[1]DME-A/Alou-B	[2]SLC-2E		S
Explorer 32	5/25/66	Delta-38	AE-B (S-6a)	17B	238	S
Explorer 33	7/1/66	[3]Delta-39	IMP-D	17A	3329	S
Explorer 34	5/24/67	[3]Delta-49	IMP-F	[2]SLC-2E		S
Explorer 35	7/19/67	[3]Delta-50	IMP-E (lunar)	17B	1073	S
Explorer 38	7/4/68	[3]Delta-57	RAE-A	[2]SLC-2E		S
Explorer 41	6/21/69	Delta-69	IMP-G	[2]SLC-2W		S
Explorer 43	3/13/71	[3]Delta-83	IMP-I	17A	9135	S
Explorer 47	9/22/72	[3]Delta-90	IMP-H	17B	1361	S
Explorer 49	6/10/73	[3]Delta-95	RAE-B (lunar)	17B	2314	S
Explorer 50	10/25/73	[3]Delta-97	IMP-J	17B	3964	S
Explorer 51	12/15/73	[3]Delta-99	AE-C	[2]SLC-2W		S
Explorer 54	10/6/75	[3]Delta-115	AE-D	[2]SLC-2W		S
Explorer 55	11/19/75	[3]Delta-117	AE-E	17B	2708	S
[4]ISEE 1&2	10/22/77	[3]Delta-135	[1]ISEE A&B	17B	1133	S
[4]IUE	1/26/78	[3]Delta-138	IUE	17A	3990	S
[4]ISEE 3	8/12/78	[3]Delta-144	ISEE-C	17B	6366	S
Dynamic Explorer	8/3/81	[3]Delta-155	[1]DE A&B	[2]SLC-2W		S
SME/UOSAT	10/6/81	[3]Delta-157	[1]SME/UOSAT	[2]SLC-2W		S
OSO (Orbiting Solar Observatories)						
OSO 1	3/7/62	Delta-8	OSO-A (S-16)	17A	124	S
OSO 2	2/3/65	Delta-29	OSO-B2 (S-17)	17B	304	S
OSO	8/25/65	Delta-33	OSO-C	17B	466	U
OSO 3	3/8/67	Delta-46	OSO-E1	17A	6936	S
OSO 4	10/18/67	Delta-53	OSO-D	17B	153	S
OSO 5	1/22/69	Delta-64	OSO-F	17B	5960	S
OSO 6/PAC	8/9/69	[3]Delta-72	[1]OSO-G/PAC	17A	4744	S
OSO 7/TETR 3	9/29/71	[3]Delta-85	[1]OSO-H/TETR-D	17A	4617	S
OSO 8	6/21/75	[3]Delta-112	OSO-I	17B	5300	S
OGO (Orbiting Geophysical Observatories)						
OGO 1	9/4/64	Atlas-Agena-10	OGO-A	12	4307	S
OGO 2	10/14/65	[3]Thor-Agena-4	OGO-C	[2]SLC-2E		P
OGO 3	6/6/66	Atlas-Agena-16	OGO-B	12	6423	S
OGO 4	7/28/67	[3]Thor-Agena-8	OGO-D	[2]SLC-2E		S
OGO 5	3/4/68	Atlas-Agena-26	OGO-E	13	3366	S
OGO 6	6/5/69	[3]Thor-Agena-11	OGO-F	[2]SLC-2E		S
OAO (Orbiting Astronomical Observatories)						
OAO 1	4/8/66	Atlas-Agena-15	OAO-A1	12	0050	P
OAO 2	12/7/68	Atlas-Centaur-16	OAO-A2	36B	1979	S
OAO	11/30/70	Atlas-Centaur-21	OAO-B	36B	2969	U
OAO 3 (Copernicus)	8/21/72	Atlas-Centaur-22	OAO-C	36B	8508	S
HEAO (High Energy Astronomy Observatories)						
HEAO 1	8/12/77	Atlas-Centaur-45	HEAO-A	36B	3133	S
HEAO 2 (Einstein)	11/13/78	Atlas-Centaur-52	HEAO-B	36B	4444	S
HEAO 3	9/20/79	Atlas-Centaur-53	HEAO-C	36B	8310	S
SCATHA (Spacecraft Charging At High Altitudes)						
[4]SCATHA	1/30/79	Delta-148	SCATHA	17B	7802	S
SMM (Solar Maximum Mission)						
SMM	2/14/80	Delta-151	SMM	17A	5999	S

GALAXY						
[4]Galaxy I	6/28/83	[3]Delta-170	Galaxy A	17B	4241	S
[4]Galaxy II	9/22/83	[3]Delta-173	Galaxy B	17A	5853	S
[4]Galaxy III	9/21/84	[3]Delta-178	Galaxy III	17B	4591	S
MARISAT (U.S. Maritime Communications Satellites)						
[4]Marisat 1	2/19/76	[3]Delta-120	Marisat-A	17B	4200	S
[4]Marisat 2	6/9/76	[3]Delta-124	Marisat-B	17A	2030	S
[4]Marisat 3	10/14/76	[3]Delta-127	Marisat-C	17A	6911	S
FLTSATCOM (U.S. Fleet Satellite Communications Spacecraft)						
[4]FLTSATCOM 1	2/9/78	Atlas-Centaur-44	FLTSATCOM-A	36A	2321	S
[4]FLTSATCOM 2	5/4/79	Atlas-Centaur-47	FLTSATCOM-B	36A	2513	S
[4]FLTSATCOM 3	1/17/80	Atlas-Centaur-49	FLTSATCOM-C	36A	8228	S
[4]FLTSATCOM 4	10/30/80	Atlas-Centaur-57	FLTSATCOM-D	36A	5335	S
[4]FLTSATCOM 5	8/6/81	Atlas-Centaur-59	FLTSATCOM-E	36A	8189	S
[4]FLTSATCOM 7	12/4/86	Atlas-Centaur-66	FLTSATCOM-G	36B	0692	S
COMSTAR (U.S. Domestic Communications Satellites)						
[4]Comstar D-1	5/13/76	Atlas-Centaur-38	Comstar D-1	36A	2211	S
[4]Comstar D-2	7/22/76	Atlas-Centaur-40	Comstar D-2	36B	6909	S
[4]Comstar D-3	6/29/78	Atlas-Centaur-41	Comstar D-3	36B	3888	S
[4]Comstar D-4	2/21/81	Atlas-Centaur-42	Comstar D-4	36A	6767	S
SKYNET (British Communications Satellites)						
[4]Skynet 1	11/21/69	[3]Delta-74	Skynet-A	17A	155	S
[4]Skynet 2	8/19/70	[3]Delta-80	Skynet-B	17A	5980	S
[4]Skynet	1/18/74	[3]Delta-100	Skynet-2A	17B	8232	U
[4]Skynet 3	11/22/74	[3]Delta-105	Skynet-2B	17B	3710	S
TELESAT (Canadian Domestic Communications Satellites)						
[4]Telesat 1 (Anik 1)	11/9/72	[3]Delta-92	Telesat-A	17B	2489	S
[4]Telesat 2 (Anik 2)	4/20/73	[3]Delta-94	Telesat-B	17B	5887	S
[4]Telesat 3 (Anik 3)	5/7/75	[3]Delta-110	Telesat-C	17B	7011	S
[4]Telesat 4 (Anik B)	12/15/78	[3]Delta-147	Telesat-D	17A	5929	S
[4]Telesat 6 (Anik D-1)	8/26/82	[3]Delta-164	Telesat-F	17B	6027	S
See Note 7						
NATOSAT (North Atlantic Treaty Organization Communications Satellites)						
[4]NATOSAT 1	3/20/70	[3]Delta-77	NATO-A	17A	4100	S
[4]NATOSAT 2	2/2/71	[3]Delta-82	NATO-B	17A	7911	S
[4]NATO IIIA	4/22/76	[3]Delta-122	NATO IIIA	17B	2190	S
[4]NATO IIIB	1/27/77	[3]Delta-128	NATO IIIB	17A	4499	S
[4]NATO IIIC	11/18/78	[3]Delta-146	NATO IIIC	17B	6446	S
[4]NATO IIID	11/13/84	[3]Delta-177	NATO IIID	17A	2938	S
PALAPA (Indonesian Domestic Communications Satellites)						
[4]Palapa 1	7/8/76	[3]Delta-125	Palapa-A	17A	5660	S
[4]Palapa 2	3/10/77	[3]Delta-129	Palapa-B	17A	1500	S
See Note 7						
SBS-A (Satellite Business Systems)						
[4]SBS-1	11/15/80	[3]Delta-153	SBS-A	17A	5763	S
[4]SBS-2	9/24/81	[3]Delta-156	SBS-B	17A	2703	S
See Note 7						
INSAT						
[4]Insat-1A	4/10/82	[3]Delta-161	Insat-1A	17A	7942	P
TELSTAR						
[4]Telstar 3-A	7/28/83	[3]Delta-171	Telstar-C	17A	6985	S
See Note 7						

U. S. Launch Vehicles

Vehicle Contractor/ Vehicle Name	User Agency	PROPULSION: Stage No.	PROPULSION: Engines	Stage Contractor	Stage or Motor Designation	Propellants (oxidizer/fuel)	Thrust (lb.)	DIMENSIONS & WEIGHT: Max. Dia. (ft.)*	DIMENSIONS & WEIGHT: Length (ft.)**	DIMENSIONS & WEIGHT: Launch weight (lb.)	PERFORMANCE Payload (lb.): Orbital	PERFORMANCE Payload (lb.): Escape
BASIC VEHICLES												
Martin Marietta												
Titan 34D Transtage	USAF	0	2 x 120-in. UA 1205 (strap-on)	UTC	—	Solid	246,288,000[4]	10.2	90.4	1,514,800	4,200[5]	—
		1	2 x Aerojet LR-87-AJ-11	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	529,000	10.0	78.6			
		2	1 x Aerojet LR-91-AJ-11	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	101,000	10.0	37.0			
		3	2 x Aerojet AJ10-138	Martin Marietta	Transtage	N_2O_4/N_2H_4-UDMH	16,000	10.0	14.7			
Titan 34D No Upper Stage	USAF	0	2 x 120-in. UA1205 (strap-on)	UTC	—	Solid	246,288,000[4]	10.2	90.4	1,492,200	27,800[1]	—
		1	2 x Aerojet LR-87-AJ-11	Martin Marietta	—	N_2P_4/N_2H_4-UDMH	529,000	10.0	78.6			
		2	1 x Aerojet LR-91-AJ-11	Martin Marietta	—	N_2P_4/N_2H_4-UDMH	101,000	10.0	31.3			
Titan 2 SLV No Upper Stage	USAF	1	2 x Aerojet LR-87-AJ-5	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	430,000[38]	10.0	70.2	340,000	4,200	—
			1 x Aerojet LR-91-AJ-5	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	100,000 (Vac)	10.0	23.4			
Titan 3	Commercial	0	2 x 120-in. UA1205 (strap-on)	UTC	—	Solid	246,288,000[4]	10.2	90.4	1,492,200	27,800[1]	—
		1	2 x Aerojet LR-87-AJ-11	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	529,000	10.0	78.6			
		2	1 x Aerojet LR-91-AJ-11	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	101,000	10.0	31.3			
Titan 4 Centaur G Prime	USAF	0	2 x 120 in. UA1207 (strap-on)	UTC	—	Solid	319,400,000[4]	10.2	112.9	1,910,449	10,000	—
		1	2 x Aerojet LR-87-AJ-11	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	546,000	10.0	86.5			—
		2	1 x Aerojet LR-91-AJ-11	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	104,000	10.0	32.6			—
		3	2 x P&W RL10A-3-A3	GD Space Systems	—	LOX/LH_2	33,000	14.2	29.3			—
Titan 4 IUS	USAF	0	2 x 120 in. UA1207 (strap-on)	UTC	—	Solid	319,400,000[4]	10.2	112.9	1,885,525	5,300	—
		1	2 x Aerojet LR-87-AJ-11	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	546,000	10.0	86.5			—
		2	1 x Aerojet LR-91-AJ-11	Martin Marietta	—	N_2O_4/N_2H_4-UDMH	104,000	10.0	32.6			—
		3	1 x UTC solid rocket motor-1	Boeing	—	Solid	44,100	9.5	16.4			—
			1 x UTC solid rocket motor-2		—	Solid	16,800					—
GD/Space Systems												
Atlas G, Centaur D-1A/Atlas H	NASA	½	2 x Rocketdyne YLR-89-NA7	GD/Convair	MA-5	LOX/RP-1	377,500	10.0	140.5[16]/	360,800/	5,200[15]/	3,500
		1	1 x Rocketdyne YLR-105-NA7	GD/Convair	—	LOX/RP-1	60,000	—	104.7[18]	293,000	3,000[20]	
McDonnell Douglas												
Delta 3914/ Delta 3924	NASA	1	1 x Rocketdyne RS-27	McD/Douglas	ELT Thor	LOX/RJ-1	205,000	8	73.4	420,500/	2,065[20]/	1,390/
		1	9 x Thiokol TX526-2	Thiokol	Castor 4	Solid	767,000[3]	3.3	36.6	425,300	2,430	1,670
		2	1 x TRW TR201/1 x Aerojet AJ10-118K	McD/Douglas	Delta	N_2O_4/N_2H_4-UDMH	9,850/10,000	8	19.3			
		3	1 x Thiokol TE 364-4	McD/Douglas	—	Solid	15,000	3.2	6.8			
Delta 3910/PAM-D[21] Delta 3920/PAM-D[21]	NASA	1	1 x Rocketdyne RS-27	McD/Douglas	ELT Thor	LOX/RP1	207,000	8	73.4	422,100/	2,450[20]/	1,740/
		1	9 x Thiokol TX526-2	McD/Douglas	Castor 4	Solid	767,000[3]	3.3	36.6	428,322	2,830	2,000
		2	1 x TRW TR201/1 x Aerojet AJ10-118K	McD/Douglas	Delta	N_2O_4/N_2H_4-UDMH	9,850/10,000	8	19.3			
		3	1 x Thiokol Star 48	McD/Douglas	PAM-D	Solid	15,000	4	7.2			
Delta 6920 (has 1st two stages only) Delta 6925 (3 stages)	USAF	1	1 x Rocketdyne RS-27	McD/Douglas	Extra ELT Thor	LOX/RP1	207,000	8	85.4	462,900	3,260[20]	—
		1	9 x Thiokol TX-780	McD/Douglas	Castor 4A	Solid	878,000	3.3	36.6			
		2	1 x Aerojet AJ10-118K	McD/Douglas		N_2O_4/N_2H_4-UDMH	10,000	8	19.3			
		3	1 x Thiokol Star 48B	McD/Douglas	PAM-D	Solid	15,000	4	7.2			
Delta 7920 (has 1st two stages only) Delta 7925 (3 stages)	USAF	1	1 x Rocketdyne RS-27	McD/Douglas	Extra ELT Thor	LOX/RP1	201,000	8	85.9	483,000	3,720[20]	—
		1	9 x Hercules GEM	McD/Douglas	Gr-Ep Motor (GEM)	Solid	851,000	3.3	36.6			
		2	1 x Aerojet AJ10-118K	McD/Douglas		N_2O_4/N_2H_4-UDMH	10,000	8	19.3			
		3	1 x Thiokol Star 48B	McD/Douglas	PAM-D	Solid	15,000	4	7.2			
Vought												
Scout SLV-1A	NASA, USAF	1	1 x UTC Algol 3	LTV	Algol 3A	Solid	107,000	3.7	75.1	47,200	400[10]	75
		2	1 x Thiokol Castor 2	LTV	Castor 2A	Solid	61,800	—	—			
		3	1 x Thiokol Antares 3	LTV	Antares 3A	Solid	21,000	—	—			
		4	1 x Thiokol Altair 3	LTV	Altair 3	Solid	5,700	—	—			
UPPER STAGES												
GD/Space Systems												
Centaur D-1A/D-1T[13]	NASA	Varies	2 x P&W RL10A-3-3A	GD/Convair	Centaur	LOX/LH_2	33,000	10.0	30.0	35,000	5,200[16]/ 17,500[17]	3,500/ 13,000
Martin Marietta												
Transtage	USAF	Varies	2 x Aerojet AJ10-138	Martin Marietta	Transtage	N_2O_4/N_2H_4-UDMH	16,000	10	15.0	27,000	4,200[5]	4,000
Fairchild/Space												
Stage Vehicle Sys.	USAF	2	2 x Thiokol TE-M-364-4	Fairchild/Space	SGS Blk.1	Solid	15,500	4.6	10.3	5,520	—	
Orbit Insertion Sys.	USAF	1	1 x Thiokol TE-M-616	Fairchild/Space	OIS	Solid	6,000	4.6	5.9	1,283	—	—
McDonnell Douglas												
Stage Vehicle Sys. (SGS-II)	USAF	1-2	2 x Thiokol Star-48	McD/Douglas	SGS-2	Solid	15,000	4.0	13.0	11,700	1,800[20]	—
STS/PAM-A	NASA	1	1 x Thiokol (MM3)	McD/Douglas	PAM-A	Solid	35,200	5.0	7.5	12,760	4,400[20]	2,530
STS/PAM-D	Varies	Varies	1 x Thiokol Star-48	McD/Douglas	PAM-D	Solid	15,000	4.0	6.5	7,800	2,750[20]	1,830
STS/PAM-DII	Varies	1	1 x Thiokol PAM-DII	McD/Douglas	PAM-DII	Solid	17,800	5.3	6.5	12,270	4,080	2,300
Boeing												
IUS	USAF, NASA	1-2	SRM-1	Boeing	SRM-1	Solid	44,100	9.5	16.4	32,311	5,000-6,000	11,023[20]/- 3,307[24]
			SRM-2	—	SRM-2	Solid	16,800					
Orbital Sciences												
Transfer Orbit Stage	Varies	Varies	SRM-1	Orbital Sciences	TOS	Solid	44,100	9.6	10.7	24,010	13,400[20]	7,800
Apogee and Maneuvering Stage	Varies	Varies	Rocketdyne RS-51	Orbital Sciences	AMS	N_2O_4/MMH	2,650	12.0	5.4	11,280	5,800[20]	2,880
TOS/AMS	Varies	Varies	SRM-1, Rocketdyne RS-51	Orbital Sciences	TOS/AMS	Solid / N_2O_4/MMH	44,100 / 2,650	12.0	15.7	35,300	6,500	10,100

See International Launch Vehicles for abbreviations and notes

U. S. Spacecraft

Spacecraft Name	Contractor/User	Weight (lb.)	Launch Vehicle	Remarks and Purpose/First Launch
NASA				
Space Shuttle		4.16 million total		Multi-role reusable space system/4-12-81.
Orbiter	Rockwell International	150,000		Reusable spacecraft, 65,000 lb payload. Three 470,000-lb.-thrust liquid-fuel engines.
Main engine	Rockwell International//Marshall S.F.C.	7,000		
External tank	Martin Marietta/Marshall S.F.C	1.68 million		Expendable tank for main engines. 66,000 lb
Solid booster	Morton Thiokol, MDAC, USBI, Marshall S.F.C.	1.28 million		Two reusable 3.1 million-lb.-thrust boosters.
OMS engine	Aerojet Tech. Systems	300		Two reusable 6,000-lb.-thrust engines.
Orbital Maneuvering Vehicle	TRW/Marshall S.F.C	17,000 (fueled)	Space Shuttle	Satellite retrieval & repair vehicle. 1993.
Voyager 1, 2	JPL	1,742	Titan 3E/Centaur/ TE-364-4	Study of Jupiter (79), Saturn (80-81), Uranus (86), Neptune (89)/8-20-77, 9-5-77.
Landsat 4, D-prime	GE/Goddard S.F.C.	4,400	Delta	Earth resources satellite program/7-16-82
NOAA6,9,10,H,I,J,K,L,M	RCA/Goddard S.F.C./NOAA; Ford	3,200/3,800	Atlas E	Polar Metsats/ 6-79, 12-84, 9-86, 12-87, 3-89, 6-90, 9-91.
GOES-4, 5, 6, G, H, I, J, K	Ford Aerospace/Hughes/ Goddard S.F.C./NOAA	1,841/12,340 2,891 (I, J, K)	Delta Shuttle (I, J, K)	Geostationary weather satellite. 9-80, 5-81; 4-83, 2-87, TBD.
Galileo	JPL	5,500	Space Shuttle	Jupiter orbiter and entry probe/1989.
Hubble Space Telescope	NASA-Marshall, ESA/NASA-Goddard, Lockheed, Perkin-Elmer	25,500	Space Shuttle	2.4-meter optical instrument will be launched in 1989 for long duration orbit.
Dynamic Explorer 2	RCA/Goddard S.F.C.	915	Delta	Magnetosphere elec. forces study/8-3-81.
GRO	TRW/Goddard S.F.C.	35,000	Space Shuttle	Map gamma ray sources/1990.
TDRSS C, D, E	SPACECOM, TRW, Goddard S.F.C.	4,700	Space Shuttle/IUS	Tracking and data-relay satellite/2-88; 9-88; 1991.
Ulysses	ESA/JPL	814	Space Shuttle	Fly out-of-eliptic above solar poles/1990.
Solar Mesophere Explorer	Ball Aerospace/JPL	915	Delta	Solar effects on atmos. ozone/10-6-81.
SCATHA	Martin Marietta/Air Force	788	Delta	Study buildup elec. chrgs. at HEO/1-30-79.
AMPTE-CCE, IRM, UKS Coop w/W. Germany	CCE-APL, Goddard S.F.C., IRM-W. Germany UKS-G. Britain	220/690/45 Kg	Delta	Active Magnetosphene Particle Tracer Experiment. Single veh. launch/8-16-84.
ERBS	Ball Aerospace/Goddard S.F.C.	5,000	Space Shuttle	Earth Radiation Budget Satellite/10-5-84.
CRRES-Combined Radiation and Release Satellite	Ball Aerospace/Marshall S.F.C./Air Force	4,000	Atlas Centaur	First 60 days, NASA chemical rel. in GEO, then A.F. radiation mapping/effects/1990. meas. studies mission./89-92.
MPF-Materials Process Fac.	Ball Aerospace (commercial)	15,000	Space Shuttle	Comm'l mat. process. exp./1985.
COBE-Cosmic Background Explorer	NASA/Goddard S.F.C.	5,000	Delta	900 Km. 99° inclination orbit to measure residual radiation from "Big Bang" 2-89.
AEROS	Ball Aerospace/Space America	436	Shuttle/Conestoga	Earth resources, 3-axis spin stabilized/1986.
UARS-Upper Atmosphere Research Satellite	GE/Goddard S.F.C.	15,000	Space Shuttle	Study physical process stratosphere, mesosphere and lower thermosphere 10-91.
ACTS-Advanced Communications Technology Satellite	RCA/NASA	4,200 (approx.)	Space Shuttle	Ka-band-Scheduled for 1990.
Magellan	Martin Marietta/JPL	—	Space Shuttle/IUS	Venus radar mapper. April 1989.
Mars Observer	RCA/JPL	—	Shuttle/TOS	Mars Orbiter. Sept. 1992.
Commercial				
Westar 1, 2, 3/4, 5, 6, 6S	Hughes/Western Union	660/1280	Delta/Shuttle	Two 12-trans. and four 24 trans. sats./4-13-74; 10-10-74; 8-9-79/2-25-82; 6-10-82; 6 recov. 10-14-84.
Marisat 1, 2, 3	Hughes	700	Delta	Navy/Comm'l shipping /last 10/76.
Comstar 1, 2, 3, 4	Hughes	1,746	Atlas/Centaur	Four 24-trans., spin-stab. sats/last 2/81.
Spacenet	RCA/GTE/Spacenet Corp.	2,634	Ariane 3	C, Ku-band./5-22-84; 11-8-84; 1988.
G STAR	RCA/GTE Satellite Co.	2,657	Ariane 3	Ku-band 5-7-85. 3/86; 1988
SBS 1, 2, 3, 4, 5	Hughes	1,200	Delta/Shuttle/Ariane 3	10-channel digital data relay, 6 spare TWTs/11-15-80; 9-24-81; 11-11-82; 8-30-84.
Telstar 3 1, 2, 3	Hughes	1,463	Delta/Shuttle	24-transponder, 6/4 GHz satellites op. by AT & T/7-9-83; 9-1-84, 6-85.
Galaxy 1, 2, 3	Hughes	1,222	Delta	Hughes comm. sats.; 24 trans. 6/4 GHz. G-1 all cable/6-28-83; 9-27-83; 9-84.
American Satellite Co.	RCA/American Sat. Co.	2,800	Space Shuttle	C, Ku-band 8/27/85; 1990.
RCA Americom Ku-band	RCA/RCA Americom	4,245	Space Shuttle	Ku-band 11/26/85, 1/86, 1990.
STC/DBS	RCA/Sat. T.V. Corp.	2,750 (approx.)	Shuttle/Ariane	Launch sched. undetermined.
DBSC	Ford Aerospace	3,500	Ariane/Shuttle	Direct broadcast T.V./Mid-88.
Fordsat	Ford Aerospace	2,450	Ariane/Shuttle	Fixed service c/Ku-band./Mid-88.
Eosat 1, 2	RCA/Hughes	—	—	Earth observation/scheduled 1988.
Military				
DSCS-2	TRW/Defense Dept.	1,195	Titan 34/Transtage	Synch. orbit. with earth-coverage and spotbeam antennas provides up to 1,300 duplex voice channels/11-2-71.
DSCS-3	GE/Defense Dept.	1,947	Titan 34D/Transtage Space Shuttle/Titan 4	Three-axis-stabilized, next-generation synchronous communications satellite/10-30-82.
FleetSatCom 1,2,3,4,6,7,8	TRW/Navy/Air Force	2,100 2,300	Atlas/Centaur	UHF Comm. between ships, shore-to-ship, ship-to-aircraft and SIOP forces. Carries USAF Satellite Comm. System (AFSATCOM)-2-9-87. No. 5 damaged in orbit. 5-4-79; 1-17-80; 10-30-80, 8-6-81.
Satellite Data System	Hughes/Air Force	—	—	Provides UHF communications for strategic forces, communications between Satellite Control Facility ground stations, strategic data relay.
Broad Coverage Photo Recon	Lockheed/Air Force	25,000 (est.)	—	Big Bird satellite provides both radio transmission and recoverable photo return; 155 x 100-mi. orbit at 96.4 deg.
KH-11 Strategic Recon	USAF/CIA	25,000 (est.)	—	Broad-coverage digital-image-transmission recon satellite; 275 x 185-mi. orbit at 97 deg./12-19-76.
High Resolution Film Recon	USAF	—	—	Highest resolution film return recon satellite; 80 x 215-mi. orbit at 96.4 deg.
Ocean Surveillance 1	Navy	—	Atlas F	All-weather sea surveillance/ 3-11-76, 3 spacecraft per launch.
Defense Support Program (Code 647)/Advanced	TRW/Aerojet/Air Force	2,000	—	To detect launch of ICBMs, SLBMs using IR sensors in synch. orbit/5-5-71; 1986.
Navy Navigation Satellite System (Transit)	RCA/Navy	301	Scout	Satellites in 600-mi. polar orbits/1970, 1973. Still operational.
Nova	RCA Astro-Electronics/Navy	—	Scout	Navigation/5-14-81; 10-11-84.
Global Positioning System (Navstar)	Rockwell/Defense Dept.	1,157 (Block 1) 2,000 (Block 2)	Atlas E/F,Shuttle (1988) MLV (1989)	Developmental system with 6 satellites in 12-hr., subsynchronous orbit/ 2-22-78. Last launch on expendable vehicle 10-8-85. First shuttle launch in 1988.
Defense Meteorological Satellite Program	RCA/Defense Dept.	1,131 (Block 5D-1) 1,161 (Block 5D-2) 3,775 (Block 5D-3)	LV-2F, Atlas E Atlas E Titan 2 SLV	Provide global meterological info./Block 5D-2,12-19-82/Block 5D-3 TBD. LV-2F, AtlasE Atlas E Titan 2 SLV
N-Ross	—/Navy	—	Titan 2 SLV	Oceanographic surface information. No launch date.
Ferret (Code 711)	Lockheed/Sanders/Air Force	500 (est.)	Thor/Agena	Second-generation electromagnetic-reconnaissance satellite to be superceded by new Hughes design (Code 711).
Clipper Bow	Navy	—	Space Shuttle	Ocean surveillance sat. with active radar.
Leasat	Hughes/Navy	2,800	Space Shuttle	Follow-on to FleetSatCom. 8-31-84
SOOS-Stacked Oscars on Scout	RCA/Navy	—	Scout	Navigation-dual launches 8/85, 9/87.
Relay Mirror Experiment	Ball Aerospace/Defense Dept.	2,300	Delta	Relay Mirror Technology. 8/88

Abbreviations
APL—Applied Physics Laboratory of Johns Hopkins University;
BA—British Aerospace Corp.,
CCE—Change Composition Explorer,
Casar-Consortium of ASAT, SETIS and Aerospatiale;
CNES—French National Center for Space Studies,
CNRS—French National Center for Space Research,
Cosmos—Consortium of ECTA, GEC Marconi, SAT, Selenia, Aerospatiale,
CRA—Centro Ricerche Aerospaziale,
ESC—European Communications Satellite,
GE—General Electric,
IRAS—Infrared Astronomical Sat.;
HEO—high earth orbit,
IRM—Ion Release Module;
ISAS—Japanese Inst. of Space & Astronautical Science,
JPL—Jet Propulsion Laboratory,
LEO—low earth orbit,
MBB—Messerschmitt-Boelkow-Blohm,
MCI—Matsushita Communications Industries,
MDAC—McDonnell Douglas Astronautics Co.;
Melco—Mitsubishi Electric Co.,
MESH—Matra, ERNO, Saab, HSD, Aeritalia,
MHI—Mitsubishi Heavy Industries,
NEC—Nihon Electric Co.;
NOAA—National Oceanic and Atmospheric Administration (U.S.);
NRC—National Research Council,
NTT—Nippon Telegraph & Telephone Public Corp.;
OMS—Orbital Maneuvering System,
SCATHA—Spacecraft Charging at High Altitude,
SEP—Societe Europeenne de Propulsion (France),
STAR—Thomson-CSF, SEP, Dornier, CGE, FIAR, Montedel Laben,Fokker-VFW, Sener, Ericsson, Contraves,
trans—transponder,
UKS—United Kingdom Satellite,
USBI—United Space Boosters, Inc

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6.5 STS PROGRAM STATISTICS

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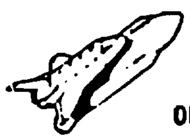
FACTORS WHICH AFFECT LAUNCH RATE INCLUDE:

- GROUND TURNAROUND TIME
- GROUND PROCESSING ANOMALIES (SERIAL HITS)
- MISSION DURATION
- GROUND PROCESSING MANPOWER AND SHIFTING
- ORBITER MODIFICATIONS
- ORBITER "OUT OF SERVICE" TIME
- LAUNCH WINDOWS
- WEATHER EFFECTS
- NON-KSC LANDINGS
- VAFB/KSC ORBITER TRANSFERS
- MAJOR FLIGHT OR GROUND HARDWARE/SOFTWARE PROBLEMS
- LOGISTICS – SPARES AVAILABILITY
- ORBITER FLEET SIZE
- FACILITIES AVAILABILITY



KSC SHUTTLE OPERATIONS	THREE ORBITER FLEET KSC LAUNCH RATE CAPABILITY STUDY	NAME: R. SIECK ORG: GM DATE: 6/86

SHUTTLE PROCESSING TIME DRIVERS

O STANDARD CRITICAL PATH PROCESSING DRIVERS

- o TEST REQUIREMENTS (OMRSD)
- o PLB DECONFIGURATION/RECONFIGURATION REQUIREMENTS
- o PL/EXPERIMENT OFFLOAD REQUIREMENTS
- o PLB CLEANLINESS REQUIREMENTS
- o STANDARD MAINTENANCE REQUIREMENTS
- o STANDARD TPS TILE TASKS

O NON-STANDARD PROCESSING DRIVERS

- o ORBITER MOD REQUIREMENTS
- o DEFERRED WORK REQUIREMENTS
- o TIME/CYCLE MAINTENANCE REQUIREMENTS
- o IN-FLIGHT ANOMALY RESOLUTION REQUIREMENTS
- o IN-PROCESSING ANOMALY RESOLUTION REQUIREMENTS
- o STRUCTURAL INSPECTION REQUIREMENTS AND RESULTANT FINDINGS RESOLUTION
- o MISSION PERFORMANCE R/R REQUIREMENTS
- o TAIL CONE/FERRY KIT INSTL./REMOVAL REQUIREMENTS

O OTHER PROCESSING DRIVERS

- o SPARES AVAILABILITY/CANNIBALIZATION REQUIREMENTS
- o ELECTRICAL CONNECTOR RETEST REQUIREMENTS
- o OMRSD IN-FLOW CHANGES
- o REAL TIME (DAILY PRCBD) WORK REQUIREMENTS
- o ANOMALY CORRECTIVE ACTION RETEST REQUIREMENTS
- o SAFETY REQUIREMENTS/CONSTRAINTS
- o FACILITY ANOMALY RESOLUTION AND OUTAGES
- o WEATHER CONSTRAINTS (PAD OPS)
- o LATE PAYLOAD INSTALLATION REQUIREMENTS
- o LATE PAYLOAD BAY ACCESS REQUIREMENTS

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6.5.2 OPERATIONS COST & MANPOWER DATA

LIFE CYCLE COST BASIS

"The estimated full costs are particularly sensitive to the number of flights, because fixed costs, either operational or capital, must be spread over a smaller base if flights are less than 24 per year estimated by NASA. In table 3 of my full testimony, there is an indication of the sensitivity of the estimates. For example, if there are only 12 flights instead of 24 in 1989, the average full cost increases to $258 million."

SOURCE: Eric Hanushek, Deputy Director, Congressional Budget Office. (Congressional hearings before the Subcommittee on Science, Technology, and Space — Fiscal 1986)

FY 1985 CONGRESSIONAL BUDGET
COST PER FLIGHT OPERATIONS COSTS
(RY $ IN MILLIONS)

	ACTUALS											
	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94
	4 FLTs	4 FLTs	8 FLTS									
SRB	334.2	397.9	464.2	539.7	652.3	658.2	689.1	673.8	664.3	681.5	661.5	475.4
ET	283.6	300.0	415.8	463.5	482.2	532.4	549.8	586.8	602.7	591.9	494.1	273.5
LAUNCH OPERATIONS	326.5	340.1	347.5	369.7	388.7	394.5	412.5	431.1	450.5	470.7	491.9	514.0
PROPELLANTS	19.9	24.0	30.3	32.3	40.0	33.5	33.6	35.1	36.7	38.3	40.1	41.9
GSE	22.0	22.4	24.1	25.7	26.8	28.0	29.5	30.8	32.2	33.6	35.1	36.7
FLIGHT OPERATIONS	259.6	315.5	345.3	405.3	405.4	419.7	434.5	456.1	476.9	499.5	522.8	547.2
ORBITER HARDWARE	129.4	160.0	162.6	207.9	205.6	230.0	232.4	242.9	253.8	265.2	277.1	269.6
CREW EQUIPMENT	20.8	29.8	36.3	47.5	53.8	59.5	60.5	63.2	66.1	69.0	72.1	75.4
SSME	15.0	38.0	51.6	75.9	76.6	65.6	60.2	73.9	73.6	28.8	10.0	6.1
CONTRACT ADMIN.	11.8	13.3	17.1	20.8	21.6	22.7	22.7	23.7	24.8	25.9	27.1	28.3
SUBTOTAL-SHUTTLE OPS	1422.8	1641.0	1894.8	2188.3	2353.0	2444.1	2524.8	2617.4	2681.6	2704.4	2631.8	2288.1
NETWORK SUPPORT	6.6	14.0	20.4	30.8	42.6	48.6	52.7	55.5	57.8	60.4	62.8	65.8
R&PM	245.7	255.0	274.2	285.8	292.7	307.5	320.8	335.3	350.4	366.1	382.6	399.8
TOTAL COST PER FLT	1675.1	1910.0	2189.4	2504.9	2688.3	2800.2	2898.3	3008.2	3089.8	3130.9	3077.2	2753.7
COST DATA BASE		1916.9	2243.9	2538.6	2668.0	2732.3	2779.0	2968.9	3048.3	3145.1	3175.1	3000.4

6.5.2 OPERATIONS COST & MANPOWER DATA

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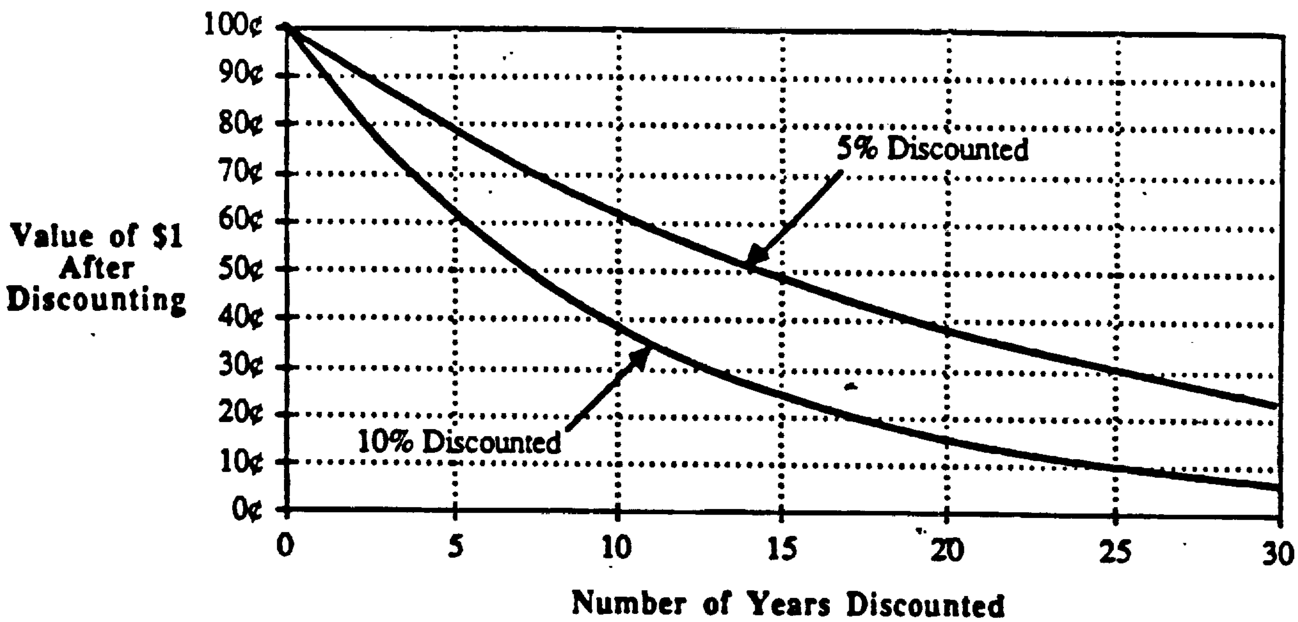
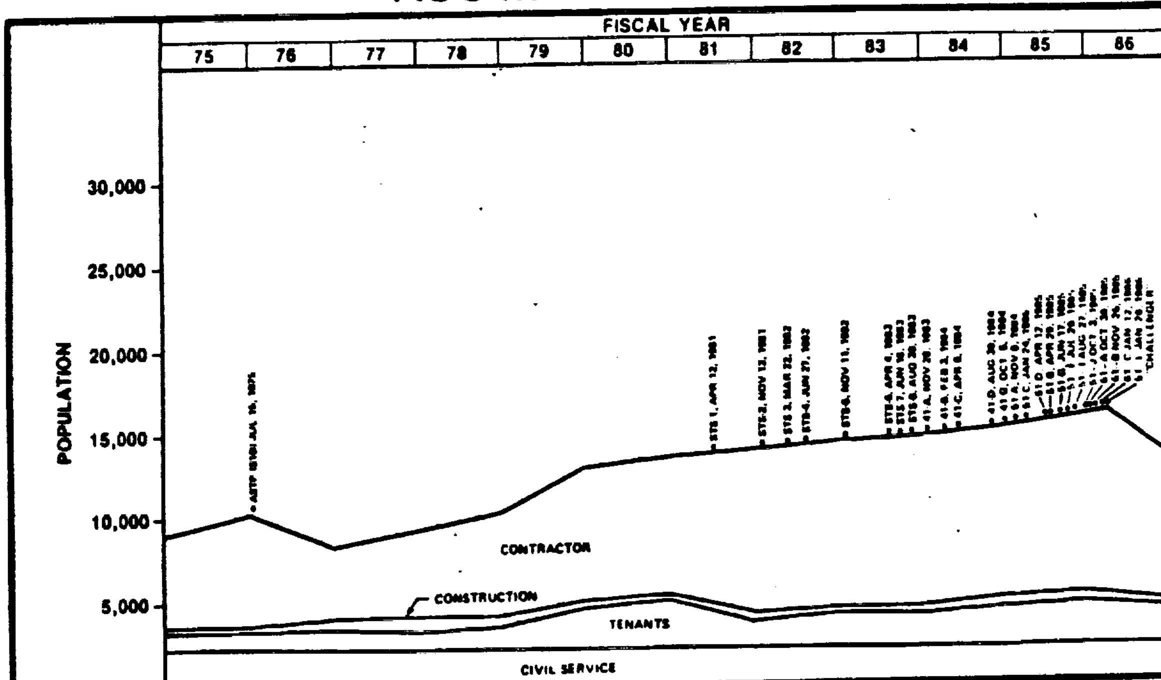


Figure 6.1.5-1. Effect of Discounting on the Value of a Dollar for 5% and 10% Discount Rates Over a 30 Year Period

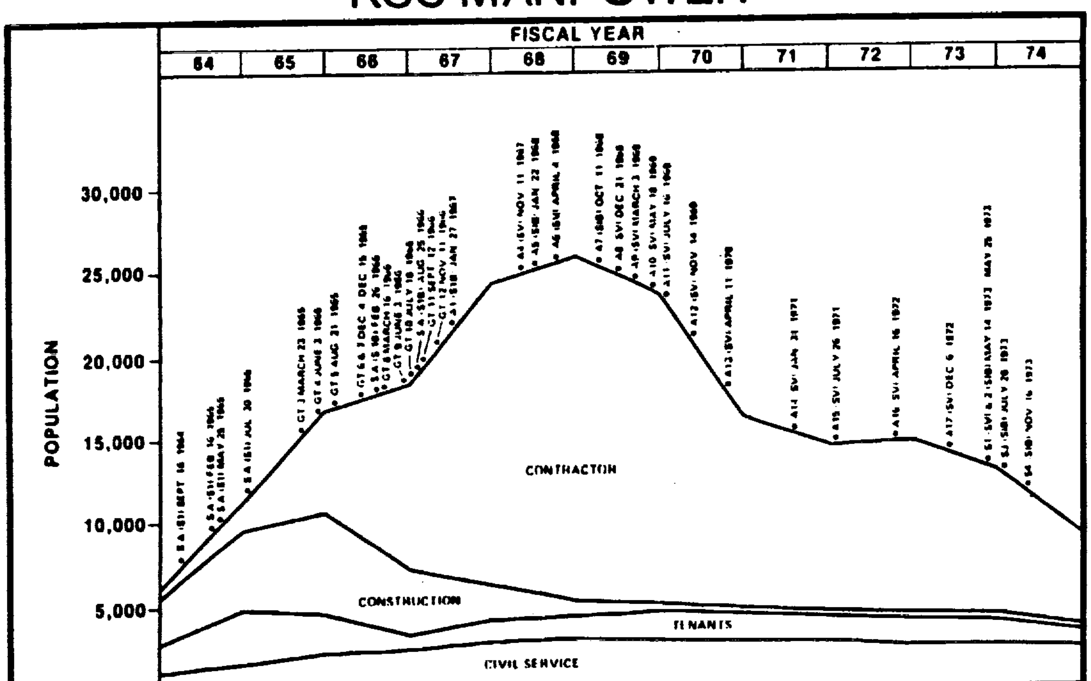
KSC MANPOWER



	75	76	77	78	79	80	81	82	83	84	85	86
TOTAL	10,368	8,441	9,376	10,352	13,002	13,688	14,004	14,391	14,686	15,133	16,067	13,664
CONTRACTOR	6,655	4,534	5,372	6,250	8,040	8 528	9,824	10,151	10,322	10,339	11,055	9.157
CONSTRUCTION	243	501	756	532	318	146	363	173	287	393	440	227
TENANTS	1,211	1,147	1,034	1,388	2,451	2,814	1,679	1,963	1,996	2,338	2,492	2,230
CIVIL SERVICE	2,259	2,259	2,215	2,182	2,193	2,201	2,138	2,104	2,081	2,063	2,080	2,050
STS LAUNCHES							1	3	4	4	8	5

APRIL 1987

KSC MANPOWER



	64	65	66	67	68	69	70	71	72	73	74
TOTAL	11,230	16,819	18 482	24,404	25,895	23,620	16,235	14,470	14 642	12 841	9 246
CONTRACTOR	1,958	6,356	11,567	18,451	20 934	18 845	11,712	10,259	10 546	8,808	5 811
CONSTRUCTION	4,525	5,870	3,633	1,906	600	233	200	170	206	212	175
TENANTS	3,237	2,316	812	1,324	1 440	1,665	1,579	1,441	1,427	1,418	951
CIVIL SERVICE	1,510	2,277	2,470	2,723	2,921	2 877	2,744	2,600	2 463	2 403	2,309

NOVEMBER 1986

S. Hrg. 99-102

NASA AUTHORIZATION FOR FISCAL YEAR 1986

(Congress, Senate, 99th Hearings
KSC-99-102)

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

NINETY-NINTH CONGRESS

FIRST SESSION

ON

NASA AUTHORIZATION FOR FISCAL YEAR 1986

FEBRUARY 26, MARCH 27, 28, APRIL 3 AND 4, 1985

Printed for the use of the
Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE
47-861 O WASHINGTON : 1985

Answer 19: The 1986 budget assures achievement of the 24 flights per year based on NASA's current best estimates of operational capability and future demands of all users. Shuttle pricing projections are based on both operational capability and projected demand. Achieving a flight rate of 24 per year is believed realistic in the time period under consideration. Therefore, it not is unrealistic to consider this number in determining pricing policy.

Question 20: Is it realistic to assume that the operating cost per flight will decrease from approximately $137 million per flight in 1984 to $39 million per flight in 1989? What are the principal factors accounting for these substantial economic gains?

Answer 20: The FY 1986 NASA budget projects that the average cost per flight (in constant 1982 dollars) will decrease from approximately $162 million per flight in FY 1985, based on 11 flights, to $84 million per flight in FY 1989, based on 24 flights. The Shuttle cost is, to a considerable extent, fixed. No matter what the flight rate is, the mission planning and launching processing teams have to be in place, facilities must be manned and skilled disciplines maintained. The largest single factor in reducing average cost per flight is the ability of this workforce to support higher flight rates without substantial expansion. Aiding in the cost per flight reduction will be efficiencies achieved by reducing vehicle turnaround times based on learning experience, and standardization of mission planning activities resulting from relaunching of payloads similar to those flown previously. In a similar manner, the hardware elements will be further down the learning curve but the fixed overhead at the manufacturers will be spread over a larger number of flights. With a doubling of the flight rate between FY 1985 and FY 1989, with planned efficiency improvements and with increased learning, NASA believes the $84 million average cost per flight by FY 1989 is definitely achievable.

Question 21: During the executive branch Shuttle pricing debate, are any steps being considered, related to pricing policy, that would make the space Shuttle more attractive to the commercial sector?

Answer 21: Considerable consideration is being given to permit a degree of flexibility in negotiating launch service agreements with the commercial sector and to continue the optimum use of the Shuttle in commercialization of space.

Question 22: Are the expectations of profit by the private sector in space realistic? Or, is a well-known space executive correct when he says that private sector investment in space is "overexposed," "overadvertised," and fought with "too much hype?"

Answer 22: As a research and development Agency, NASA is cognizant of the dangers of over-selling the economic and social benefits of space endeavors which are characterized by high-risks and long-term payback outlooks. NASA's mission in encouraging the commercial use of space is to build the research and development foundation for commercial space endeavors. Expectations of profit should be based on the current levels of private sector investment in commercial space ventures.

As NASA does not make economic projections of profits to be derived from commercial space ventures, judgments as to private sector expectations of profit in space are best left to the private sector. We are taking steps to help remove any barriers to the commercial development of space, in accordance with the President's policies.

Senator GORTON. Dr. Hanushek, again, your complete statement will be included in the record. I would greatly appreciate you summarizing it for us.

STATEMENT OF ERIC HANUSHEK, DEPUTY DIRECTOR, CONGRESSIONAL BUDGET OFFICE

Mr. HANUSHEK. I will be happy to, Senator.

Mr. Chairman, I am pleased to appear before the subcommittee to discuss space shuttle pricing policy for foreign and commercial users. The shuttle price is the key factor in determining the resources the Nation devotes to space, and whether these are provided by the public or private sector.

For instance, a high shuttle price could encourage private U.S. companies to enter the commercial launch market but would leave the shuttle underused and possibly strengthen the position of the shuttle's major competitor, Arianespace. On the other hand, a very low price would encourage the use of the shuttle but limit private competition, subsidize foreign and commercial users, and possibly encourage unprofitable expansion of the shuttle system.

The history of shuttle pricing is well-known to the Committee. Let me simply note one subtle change in pricing considerations. While it was once believed that a single price would simultaneously meet all our national space objectives, it is now clear that such is not the case.

The President is expected to submit soon a pricing proposal covering shuttle missions between 1989 and 1991. NASA has suggested a price of $87 million per flight in constant 1982 dollars that will recover average operational costs only.

In CBO's analysis of pricing policies for shuttle services, two sets of factors are considered. The first is the cost of providing shuttle services and how closely the shuttle price should be linked to the resources consumed by the use of the shuttle. The second is space policy objectives, because the shuttle price, in effect, sets priorities among conflicting space goals.

In the absence of a competitive market for shuttle services, either average or marginal costs can provide a basis for determining prices. Average cost is simply the total cost of providing the services divided by the number of flights. This is frequently referred to as a full-cost measure. Marginal cost is the cost of providing one more flight. Although an additional shuttle flight entails increased costs for fuel and other expendable supplies, many other expenditures on facilities, equipment, and people are unaffected and do not enter into the calculation of marginal costs.

CBO has provided a detailed discussion of the costs in its recent study, and I will quickly summarize them here. Three elements are key in the estimation of shuttle costs: the shuttle flight rate; the depreciation rate and discount rate used to calculate annual capital costs; and the accuracy of NASA's operational cost estimates.

The CBO-based cost estimates are provided in table 1 of my complete testimony. They are all based on an annual flight rate of 24. They represent two estimates of marginal cost: A short-run marginal cost, which is $42 million; and a long-run marginal cost, which amounts to $76 million.

We also provide three average or full cost measures. First is average full or full operational cost, which is $84 million per flight. Second, full cost less research and development [R&D] expenditures, which comes to $106 million per flight. And finally, average total cost of $150 million.

The estimated marginal costs are less than average costs because the former exclude fixed costs that do not change as additional flights are flown, but the uncertainty of the estimates is worth highlighting.

As shown in the ranges in table 2 of my full statement, the base case estimate of short-run marginal costs, $42 million, lies in a range between $28 million per flight—which is roughly NASA's estimate of short-run marginal costs—and $71 million per flight.

The long-run marginal cost estimate is $76 million per flight, in a range between $62 and $105 million. The long-run marginal cost adds to short-run marginal cost an annual capital charge that reflects a $1.7 billion replacement orbiter that might be needed to service the foreign and commercial markets.

The estimated full costs are particularly sensitive to the number of flights, because fixed costs, either operational or capital, must be spread over a smaller base if flights are less than 24 per year estimated by NASA. In table 3 of my full testimony, there is an indication of the sensitivity of the estimates. For example, if there are only 12 flights instead of 24 in 1989, the average full cost increases to $258 million.

I will now turn to the relationship between shuttle prices and policy objectives. Each of the alternative cost measures could be used as a basis for shuttle prices. The choice will directly affect how well the nation's competing space objectives are met. The three objectives that we think are most sensitive to shuttle price are: Cost recovery, efficient resource use, and encouragement of commercial activities in space.

In terms of cost recovery and efficiency, economic analysis suggests that a price equal to the marginal cost of production tends to promote the efficient use of resources, which in turn suggests that prices set for government enterprises should be based on marginal costs.

But the shuttle system is not a conventional enterprise, because many of its costs remain fixed regardless of the number of flights. These high fixed costs make the goals of cost recovery and efficiency incompatible. Specifically, because of high fixed costs, the cost of providing an additional shuttle launch is significantly less than the average cost of a launch. Simply put, recovering average costs does not lead to efficient pricing, and efficient pricing does not result in full-cost recovery.

The short-run marginal cost price, $42 million per flight, sacrifices the goal of cost recovery to ensure that the shuttle has sufficient customers to maintain a high flight rate. This price forgives shuttle users from repaying the system's fixed costs, and implicitly holds full use of the shuttle to be a preeminent policy objective. A shuttle price at this level would have no net budgetary implications, as long as NASA's cost estimates are not underestimated.

A short-run marginal cost price is valid only if excess capacity exists in the shuttle system. In contrast, the long-run marginal cost price, $76 million per flight, adopts the perspective that serving the foreign and commercial market requires including the capital costs needed to expand the system, as well as the operating costs included to perform U.S. Government in the other missions.

From a budgetary perspective, the concept of a price based on long-run marginal costs provides a litmus test to help determine the need for an additional orbiter. If the shuttle is fully booked at this price, then a new orbiter could be acquired with the confidence that its users would pay its costs, already reflected in the shuttle price. But, as with the short-run marginal cost option, the advantages of a long-run marginal cost price will not be achieved if operational costs are significantly underestimated.

It is frequently presumed that, if cost recovery is emphasized, a full-cost price would best meet this goal, but this may not be the case if flight demand for the 1989 through 1991 period is misestimated. The prices of $150 million—full cost—and $106 million—full cost less development—are high enough to permit full-cost recovery if and only if 24 flights are filled and flown in 1989.

Proponents of full-cost prices point out that, if foreign and commercial users are charged less than full costs, then they will reap, but not pay for, the benefits of the past expenditures that went into the shuttle and its technology. Moreover, full-cost prices are more comparable to the cost structures faced by private operators of competitive launch services.

But it should be remembered that the demand for the shuttle could drop dramatically in the face of high-full-cost prices. Thus, paradoxically, a full-cost price could lead to the necessity of budgetary for the shuttle system.

In fact, however, revenues from the sale of shuttle services might be maximized by charging a price below the estimated average total costs.

Full-cost prices would tend to reduce long-run Government involvement in commercial space activities since they would discourage use of the shuttle and thus reduce pressures to expand capacity. Such market information might, however, give a misleading signal about the Government's appropriate role.

There are two aspects to the commercialization of space: the promotion of a private launch industry using rockets—expendable launch vehicles, or ELV's—and the support of further commercial, industrial, and communication uses of space. The former objective is aided by higher shuttle prices, while the latter, for which launch prices are a business expense, is strengthened by lower shuttle prices.

At the shuttle's conception, its low projected costs led planners to believe that it ultimately would replace ELV's, but these low costs did not materialize, and ELV's continue to be a viable option for many space payloads.

Arianespace has priced its services to be competitive with the shuttle and plans to win a third of the launch market over the next decade. Potential private U.S. ELV firms claim that both the shuttle and Arianespace charge below-cost prices and that, if the full cost of service were reflected in their prices, American ELV's

The implications of a low shuttle price, such as a short-run marginal cost price, for space commercialization are mixed. The commercial ELV industry simply could not survive, and the potential entry of other nations, Japan, for example, might be discouraged. The reaction of Arianespace is hard to predict, but it would probably attempt to remain competitive.

Firms investing in shuttle-related launch technologies would benefit most. These include companies that are designing upperstage rockets to lift into higher orbits payloads which the shuttle has placed in low orbit. Investors interested in new space processing techniques would also be encouraged, perhaps overly so since the price would make no allowance for recapturing capital costs.

Without a more extensive analysis of demand and the costs of shuttle competitors, it is difficult to evaluate the relative prospects of ELV's, Arianespace, and the shuttle, should the shuttle system charge a mid-range price based on long-run marginal costs or full operating costs. Much really depends upon Arianespace's pricing policies and the launch demand that subsequently materializes.

In summary, Mr. Chairman, the choice of a future shuttle price will implicitly set priorities among national space policy objectives. No single price, as you quoted us in your opening statement, can meet all the nation's space goals.

Some objectives, such as the efficient short-term use of the shuttle's capacity and the encouragement of commercial activity in space are best met by a relatively low price; while others, such as the encouragement of a private domestic launch industry and perhaps full-cost recovery, suggest a higher price.

The new price proposed by NASA, now under review by the administration, represents an attempt to trade off these competing policy objectives.

Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF ERIC HANUSHEK, DEPUTY DIRECTOR, CONGRESSIONAL BUDGET OFFICE

Mr. Chairman, I am pleased to appear before this Subcommittee to discuss space shuttle pricing policy for foreign and commercial users. The Congressional Budget Office (CBO) has analyzed the cost of the shuttle, developed a set of pricing options, and explored the implications of these options for space policy objectives.

The shuttle price is a key factor in determining the resources the nation devotes to space and whether these are provided by the public or private sector. For instance, a high shuttle price could encourage private U.S. companies to enter the commercial launch market, but would leave the shuttle underused and possibly strengthen the position of the shuttle's major current competitor, Arianespace. On the other hand, a very low price would encourage use of the shuttle, but limit private competition, subsidize foreign and commercial users, and possibly encourage unprofitably expansion of the shuttle system.

The shuttle launch price is not of equal importance in achieving all of the nation's space objectives. Regardless of the price charged commercial and foreign customers, the shuttle system will fly at least 12 to 15 flights annually from 1989 through 1991, a sufficient number to maintain U.S. national prestige in space technology and to contribute substantially toward meeting the nation's objectives in space science research. A significant portion of the shuttle's national security mission also could probably be met with a flight rate lower than the 24 annual flights projected by NASA.

BACKGROUND

The President soon will submit to the Congress a new pricing policy for shuttle launch services provided to non-U.S. government users from 1989 through 1991.

These users are foreign governments and mature commercial enterprises requiring launch services for payloads such as communication satellites and remote-sensing satellites.[1]

The current price for shuttle launch, $38 million plus fees for capital facilities and insurance, was set by NASA in 1977 to recover all operating and production costs, including orbiters and related equipment.[2] But by the early 1980s, the shuttle program was behind its technical schedule, and the market for launch services proved substantially smaller than expected, forcing NASA to spread its costs over a smaller number of flights. Accordingly in 1982, when NASA set the second pricing policy for launches in the years 1986 through 1988, the price was significantly higher. But at $71 million, it still will not recover all the costs of the shuttle system. The Administration is now reviewing a new policy proposed by NASA for 1989 through 1991. This price—$87 million per flight—calls for the recovery of average operational costs only. It remains substantially less than the price implied by the original pricing policy to cover all operating and production costs.

In determining a price for space shuttle services, two sets of factors are considered. The first is the cost of providing shuttle services and how closely the shuttle price should be linked to the resources consumed by the use of the shuttle. The second is space policy objectives, because the shuttle price, in effect, sets priorities among conflicting space goals. But even with agreement on priorities, two major complications remain in pricing the shuttle. First, uncertainty exists about the level of demand for shuttle services four to six years in the future. Second, there is disagreement about how NASA cost estimates should be used to develop an appropriate price. As a result, the CBO analysis of cost bases for shuttle pricing includes both a base case and ranges around that base for each potential pricing option.

SHUTTLE COSTS

In the absence of a competitive market for shuttle services, either average or marginal costs can provide a basis for determining prices. Average cost is simply the total cost of providing a service divided by the number of units of service provided. For the shuttle, flights are usually thought of as the relevant unit. Marginal cost is the cost of providing an additional unit of service, or one more flight. While an additional shuttle flight entails increased costs for fuel and other expendable supplies, many other expenditures on facilities, equipment, and people are unaffected and do not enter into the calculation of marginal costs.

Three elements are key in the calculation of shuttle costs, and uncertainties about these lead us to consider ranges of cost estimates:

The shuttle flight rate. The base case assumes 24 flights for 1989.

The depreciation rate and discount rate used to calculate the annual capital charge for the shuttle's assets. The base case uses a 4 percent real interest rate and a 25-year systems life.

The accuracy of NASA's operational cost estimates and the division of operational costs between fixed and variable components. The base case uses the NASA total operational cost estimate and divides it equally between fixed and variable costs.

The CBO base case estimates, which are described in more detail in our recent report, include five alternative measures of cost (see Table 1):[3]

Short-run marginal cost, $42 million per flight—operational cost of an additional shuttle flight.

Long-run marginal cost, $76 million per flight—operational cost of an additional shuttle flight, plus the capital costs associated with providing services for foreign and commercial users.

Average full operational cost, $84 million per flight—the average total operational cost of a shuttle flight. Unlike marginal cost, it includes fixed operational costs.

Average cost less development, $106 million per flight. This cost averages all shuttle cost, except research and development, over the number of shuttle flights.

Average full cost, $150 million per flight. This measure averages all shuttle costs, both past and future, over all shuttle flights.

The estimated marginal costs are less than the average costs because the former exclude fixed costs that do not change as additional flights are flown. Uncertainty in these estimates is worth highlighting, as shown in the ranges in Table 2. The

[1] In contrast, so-called "infant industries" such as materials processing and pharmaceutical manufacturers receive free or very low cost transportation from NASA, until they approach financial self-sufficiency.

[2] All figures in 1982 dollars.

[3] Congressional Budget Office, Pricing Options for the Space Shuttle (March 1985).

base case estimate of short-run marginal costs—$42 million per flight—lies in a range between $28 million per flight (roughly NASA's estimate) and $71 million per flight.

TABLE 1. PRICING OPTIONS

Pricing Policy	Definition of Cost	Price Per Flight in 1989 (millions of 1982 dollars) With 24 Flights	With 18 Flights	Policy Implications
Marginal Cost Prices				
Short-Run Marginal Cost	Variable operational costs.	42	42	Maximum use of shuttle. Likely end to domestic expendable launch vehicles (ELVs). Direct competition with Arianespace. If NASA's costs are underestimated, revenues will not cover cost. High flight rate encourages future expansion.
Long-Run Marginal Cost	Variable operational costs, plus a capital charge for an orbiter dedicated to foreign and commercial flights.	76	76	Shuttle should maintain current market share and generate net federal revenues. Domestic ELV firms have little chance of success.
Full-Cost Prices				
Full Operational Cost	All operational costs. Approximation of proposed NASA policy for 1989 through 1991.	84	98	Largely the same as for long-run marginal price.
Full Cost Less Development	All operational costs, orbiters at replacement cost ($1.7 billion each), plus other investment but excluding research and development.	106	128	Shuttle will lose part of its market share unless Arianespace increases its price as well. Prospects for domestic ELVs improved but still uncertain. Less than full use of shuttle.
Full Cost	All operational costs, plus all investment valued at historic costs.	150	186	Shuttle loses all but specialized foreign and commercial payloads--flight rate will be below efficient level. Reduced net federal revenues. Domestic ELVs will do well, particularly if Arianespace increases price. Investors in new space processing may reduce planned spending. Little immediate need to expand shuttle system.

SOURCE: Congressional Budget Office.

NOTE: Estimates reflect base-case assumptions about interest rate and depreciation. Alternative assumptions would generally result in higher costs for options with capital costs. Operational costs based on estimates by NASA.

The actual cost in 1989 will depend on the flight rate between now and then and on how well NASA has estimated future operating costs and has distinguished fixed from variable costs. The base case estimate for the long-run marginal cost is $76 million per flight—in a range between $62 million and $105 million. It adds to short-run marginal cost an annual capital cost that reflects a $1.7 billion replacement orbiter, which might be needed to service the foreign and commercial market.

TABLE 2.—*Marginal cost: Range of estimates per flight*

[In millions of 1982 dollars]

Cost bases:	
Short-run marginal cost:	
Low	28
Base case	42
High	71
Long-run marginal cost:	
Low	62
Base case	76
High	105

Source: Congressional Budget Office.

Estimated full costs rise significantly as the estimated number of flights decreases, because fixed costs, either operational or capital, must be spread over a smaller base, as Table 3 shows. For example, if 18 rather than 24 flights are flown in 1989, the average full cost increases from $150 million to $186 million. With only 12 flights, it increases to $258 million.

TABLE 3.—FULL-COST PRICES UNDER VARIOUS SHUTTLE FLIGHT RATES

[In millions of 1982 dollars]

Full-cost prices	Number of flights: 12	18	24
Average total cost, including all capital costs	258	186	150
Average total cost, less research and development	170	128	106
Average operational cost (the NASA base)	126	98	84

Source: Congressional Budget Office.

SHUTTLE PRICES AND POLICY OBJECTIVES

Each of the alternative cost measures could be used as a basis for shuttle prices. The choice will directly affect how well the nation's competing space objectives are met. The three objectives most sensitive to the shuttle price are: Cost recovery; Efficient resource use; and, Encouragement of commercial activities in space.

COST RECOVERY AND EFFICIENCY

Economic analysis suggests that competitive markets yield prices approximating marginal costs and that such prices provide for efficient use of resources. When price exceeds marginal cost, society forgoes benefits because consumers are willing to pay more for the additional unit of the service than the value of the resources that went into providing it. Conversely, if marginal cost exceeds price, resources used to produce the service would be better employed in providing some alternative good or service. Thus, a price equal to the marginal cost of production tends to promote the efficient use of our resources, which in turn suggests that prices set for government enterprises should be based on marginal costs.

But the shuttle system is not a convetional enterprise because many of its costs remain fixed regardless of the number of flights. These high fixed costs make the goals of cost recovery and efficiency incompatible. Specifically, because of high fixed costs, marginal cost—the cost of providing an additional shuttle launch—is significantly less than the average cost of a launch. Simply put, recovering average costs does not lead to efficient pricing, and efficient pricing does not result in full-cost recovery.

The short-run marginal cost price, $42 million per flight, sacrifices the goal of cost recovery to ensure that the shuttle has sufficient customers to maintain a high flight rate. This price forgives shuttle users from repaying the system's fixed costs, and implicitly holds full use of the shuttle to be a preeminent policy objective. A shuttle price set at this level would have no net budgetary implications, as long as NASA's cost estimates are correct. If costs prove to have been underestimated, however, the government could end up subsidizing foreign and commercial payloads.

A short-run marginal cost price is valid only if excess capacity remains in the shuttle system. In contrast, the long-run marginal cost price, $76 million per flight, adopts the perspective that serving the foreign and commercial market requires capital costs to expand the system as well as operating costs. From a budgetary perspective, the concept of a price based on long-run marginal costs provides a litmus test to help determine the need for an additional orbiter. If the shuttle is fully booked at this price, then a new orbiter could be acquired with the confidence that its users would pay its costs (already reflected in the shuttle price). But, as with the short-run marginal cost option, the advantages of a long-run marginal cost price will not be achieved if operational costs are significantly underestimated.

It is frequently presumed that, if cost recovery is emphasized, a fullcost price would best meet this goal. But this may not be the case if flight demand for the 1989 through 1991 period is misestimated. The prices of $150 million (full cost) and $106 million (full cost less development) are high enough to permit full-cost recovery if, and only if, 24 flights are filled and flown in 1989. In fact, revenues from the sale of shuttle services may be maximized by charging a price below the estimated average total costs.

Proponents of full-cost prices point out that if foreign and commercial users are charged less than full costs, then they will reap, but not pay for, the benefits of the past expenditures that went into the shuttle and its technology. Moreover, full-cost prices are more comparable to the cost structures faced by private operators of competitive launch services.

But it should be remembered that the demand for the shuttle could drop dramatically in the face of high, full-cost prices. Thus, paradoxically, a full-cost price could lead to the necessity of budgetary subsidies for the shuttle system. Full-cost prices would tend to reduce long-run government involvement in commercial space activities since they would discourage use of the shuttle and thus reduce pressures to expand capacity. Such market information may, however, give a misleading signal about the government's appropriate role.

THE LONG-TERM COMMERCIAL DEVELOPMENT OF SPACE

There are two aspects to the commercialization of space: the promotion of a private, domestic launch industry using rockets—expendable launch vehicles (ELVs)—and the support of further commercial, industrial, and communication uses of space. The former objective is aided by higher shuttle prices while the latter, for which launch prices are a business expense, is strengthened by lower shuttle prices. The price that any user ultimately must pay depends importantly on the alternative suppliers in the launch market, and therefore CBO has concentrated on this element of commercialization.

At the shuttle's conception, its low projected costs led planners to believe that it ultimately would replace ELVs. But these low costs did not materialize, and ELVs continue to be a viable option for many space payloads. Currently, the shuttle's ELV competitors include Arianespace (an enterprise backed by the 11 nations of the European Space Agency) and, potentially, several private U.S. firms. The ELV industry offers launch services with rockets directly or indirectly developed by U.S. government efforts—Delta, Atlas Centaur, Titan and their European relative, Ariane. Arianespace has priced its services to be competitive with the shuttle and plans to win a third of the launch market over the next decade. Potential private U.S. ELV firms claim that both the shuttle and Arianespace charge below-cost prices and that, if the full cost of service were reflected in their prices, American ELVs would prove competitive.

The implications for space commercialization of a very low shuttle price, such as a short-run marginal cost price, are mixed. The U.S. commercial ELV industry simply could not survive and the potential entry of other nations (Japan, for example) might be discouraged. Although the response of Arianespace is hard to predict, continued subsidies by its European supporters appear likely. As a result, the commercial market would probably continue to be shared between Ariane and the shuttle, with the shuttle gaining some relative advantage

Firms investing in shuttle-related launch technology would benefit most from a very low price. These include companies that are designing upperstage rockets to lift into higher orbits payloads which the shuttle has placed in low orbit. Investors interested in new space processing techniques would also be encouraged, perhaps overly so since the price would make no allowance for recapturing capital costs.

Without a more extensive analysis of demand and the costs of shuttle competitors, it is difficult to evaluate the relative prospects of domestic ELVs, Arianespace, and the shuttle, should the shuttle system charge a midrange price based on long-run marginal costs or full operating costs. While a shuttle price based on long-run marginal costs might be low enough to allow NASA to compete effectively with Arianespace, it could be too low to permit domestic ELVs to survive. alternatively, under a higher price based on full costs (and perhaps a full cost less development price), the U.S. ELV industry could compete directly with Ariane and the shuttle. Although existing ELVs firms (those using the Delta and Atlas-Centaur rockets) would have a difficult time matching Arianespace's price, they would have real incentives to invest additional funds in improving these rockets or in developing new ones. From this prespective, a competitive domestic launch industry would be best promoted by launch prices that reflect full costs, unsubsidized by governments.

Proponents of charging a higher shuttle price to encourage a private domestic launch industry contend that the benefits of a strong private industry are not limited to launch privatization. According to this view, a private launch industry would enhance national security and would provide lower launch costs in the long run, thus encouraging all types of space commercialization. Lower launch costs presumably would be realized by superior private-sector cost control and technical innovation stemming from competition in the marketplace.

These benefits could be jeopardized, however, if Arianespace undercut a full-cost shuttle price with a subsidized predatory price. If investors preceived that Arianespace would use its government subsidies to prohibit the entry of U.S. ELVs, then the development of the U.S. ELV industry could be thwarted. thus, in addition to a higher shuttle price, an aggressive trade policy that sought to eliminate Ariane subsidies might be a necessary precondition to investment in U.S. ELVs.

OTHER FACTORS

A significant aspect of pricing policy concerns the time for which the price remains in effect. NASA has proposed a three-year policy, covering 1989 through 1991. The rationale is that price stability is desirable from a marketing standpoint and that the detailed engineering and construction work on communication satellites must start at least three yers before launch. A very long lead time, such as the six years from now until 1991, however, greatly increases the likehood of errors in forecasting costs and demand. One alternative to the proposed policy would be to establish a pricing principle, use it to set a price for 1989, and then to update the price each year using NASA's most recent information on costs and flight rates. This policy would implicitly have foreign and commercial users share a portion of the risk with the U.S. government.

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR GORTON AND THE ANSWERS

Question 1. Dr. Hanushek, what Shuttle pricing policy will most effectively serve to maximize the U.S. share, be it that of the Shuttle, or a domestic ELV industry, or some combination of the two, of the world satellite launch market?

Answer. Very low prices, of course, would ensure the fullest use of the shuttle, but they would not maximize U.S. revenues from the foreign and commercial launch market. It is difficult to estimate which shuttle price would result in the largest U.S. share of world launch revenues. Such calculations would require detailed analyses of the demand for launch services from 1989 through 1991 and of the probable responses of Arianespace to alternative shuttle prices. CBO has not undertaken such analyses.

Based on the information CBO has gathered, it seems unlikely that a shuttle price set high enough to allow a private domestic ELV industry to develop would also maximize the U.S. share of total launch revenues. The price that would do this would most likely fall somewhere between short-run marginal costs ($12 million in 1982 dollars) and full costs less R&D ($106 million). But the exact level that price cannot be ascertained with available information.

Question 2. Dr. Hanushek, in this ongoing debate, it has been suggested by some interested parties that a multi-tiered pricing policy which charged the nascent space processing industries marginal costs and the communications satellite owners full costs might be appropriate.

Whate are the implications of such a policy, and what is its likely impact on the allocation of the satellite launch market?

Could you comment on the merits or faults of incorporating in a pricing policy a royalty fee that is based on the income generated from activities such as space manufacturing that require Shuttle launch services?

Answer. The current pricing policy is, in effect, a two-tiered structure with a zero price charged for certain classes of payloads. Its purpose is to lower the cost of experimentation to firms with new space technology applications, like materials processing. NASA now provides this type of access to space through Joint Endevour Agreements (JEAs). It is NASA's intention that once operational status is achieved, JEA experimenters will pay full price—that is the price charged to other operational users such as communications companies. If, however, firms testing new space applications were charged marginal costs, many experiments simply would not be conducted because of the expense, combined with their inherent riskiness. Thus, the suggested policy would limit the amount of experimentation relative to the current policies.

In the pricing period under discussion, 1989–1991, none of the active experiments in materials processing (with the possible exception of the McDonnell Douglas/Johnson and Johnson venture) are close to an operational phase. The market of paying customers is limited to communications satellite and, perhaps a small number of remote sensing payloads. If a full-cost price were charged for these operational payloads, the CBO study concluded that the shuttle would have significant excess capacity, U.S. ELVs would be able to enter the market; but, as indicated above the U.S. share of the world launch market would likely be smaller than under lower prices.

Relative to the current JEA arrangement, royalty pricing would ensure that the government received a share of any windfall profits resulting from its initial subsidy of space transportation costs and, thus, would recoup a portion of the costs associated with providing such launch services. Conceptually, the royalty is no more effective than the present JEA arrangement in lowering the risk of space processing experiments. A secondary benefit of royalty pricing for private firms is that a portion of the uncertainty surround future shuttle prices would be removed for as long as a specific agreement was in place. This particular benefit could be secured in several alternative ways, however—for example, establishing and adhering to a marginal or full-cost pricing policy.

A royalty-based pricing policy shares many of the problems brought up in the current pricing policy discussion and creates several new problems. The questions of cost recovery and efficient use of the shuttle system would not be resolved by royalty pricing. In formulating the government position for the royalty level, negotiations decisions would have to be made concerning how much of the shuttle costs to recover in royalties, how much of the shuttle system capacity would be used, how to pick and choose among different shuttle users seeking experimental "free" flights, and how to respond to foreign competition.

New problems created by royalty pricing include the ownership like position conferred on the government by its sharing directly in the profitability of particular products or processes; the disincentive to private innovation posed by lowering the expectation of large additional profits resulting from space-based innovations; the sharing of costs among NASA, DOD, and foreign commercial flights; and, the more general uneasiness of some potential innovators to enter into a quasi-partnership with the government.

QUESTIONS OF SENATOR RIEGLE AND THE ANSWERS

Question 1. The CBO Report indicates that through FY 1984 approximately $20 billion in outlays were invested in shuttle system capital assets (design, development, testing and engineering, construction of facilities, production of orbiters and system capability). This figure represents 79 percent of the approximately $25 billion spent on the shuttle system in that period.

If the shuttle system were a private business or a regulated utility, how would this capital investment be recouped? Do government services normally recoup the costs associated with such capital investments or do they just write off those costs?

6.5.3 STS TURNAROUND (1985) WORKDAY COMPARISONS

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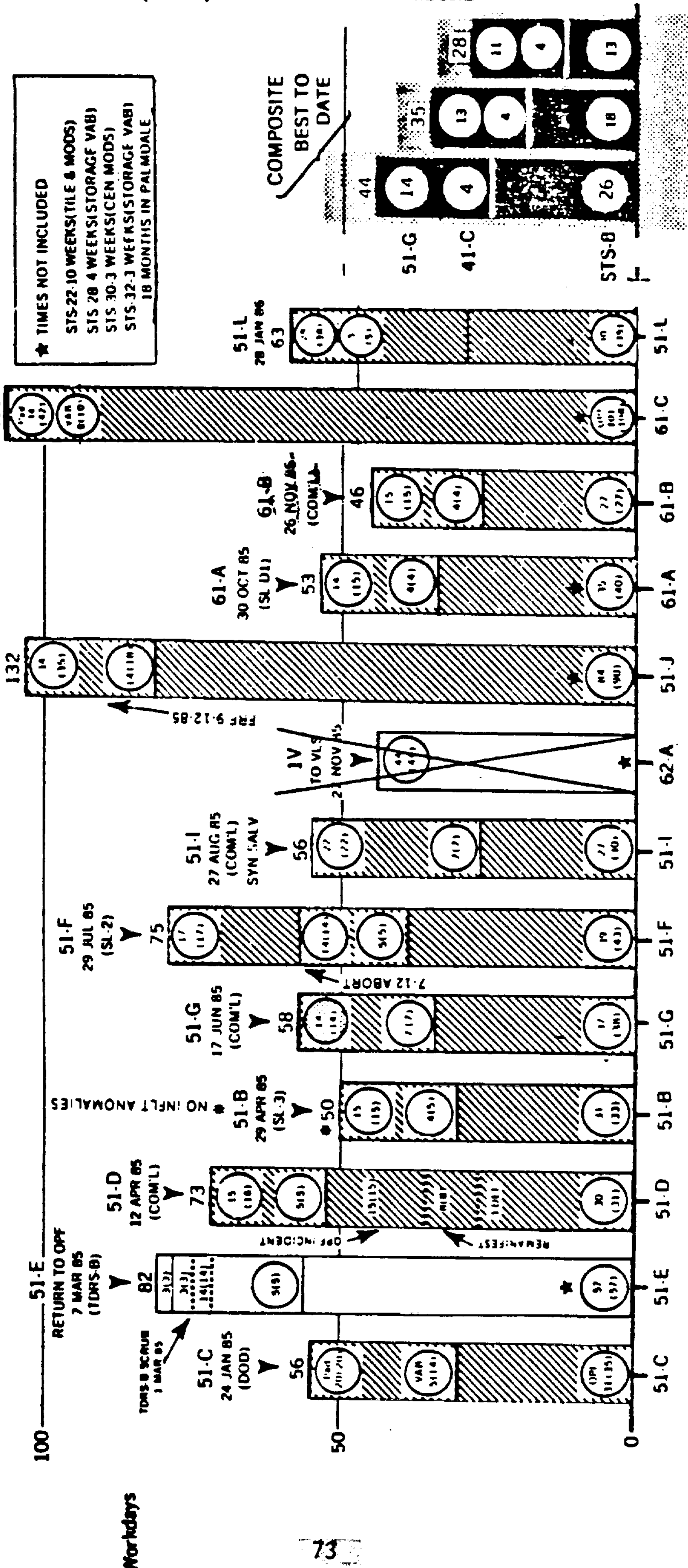
6.5.3 STS TURNAROUND (1985) WORKDAY COMPARISONS



STS Number	20	22	23	24	25	26	27	1V	28	30	31	32	33	TGT	KSC GOAL
Orbiter-FLT	103-3	099 •	103 4	099-7	103-5	099 8	103 6	103 7	104 1	099 9	104 2	102/7	099/10		
Workdays	56	82	73	50	58	75	56		132	53	46	143	63		
Calendar Days( )	(69)	(82)	(75)	(53)	(59)	(79)	(59)		(143)	(59)	(46)	160	78		

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6.5.4 STS 160-HOUR TURNAROUND vs. 51-L ACTUALS

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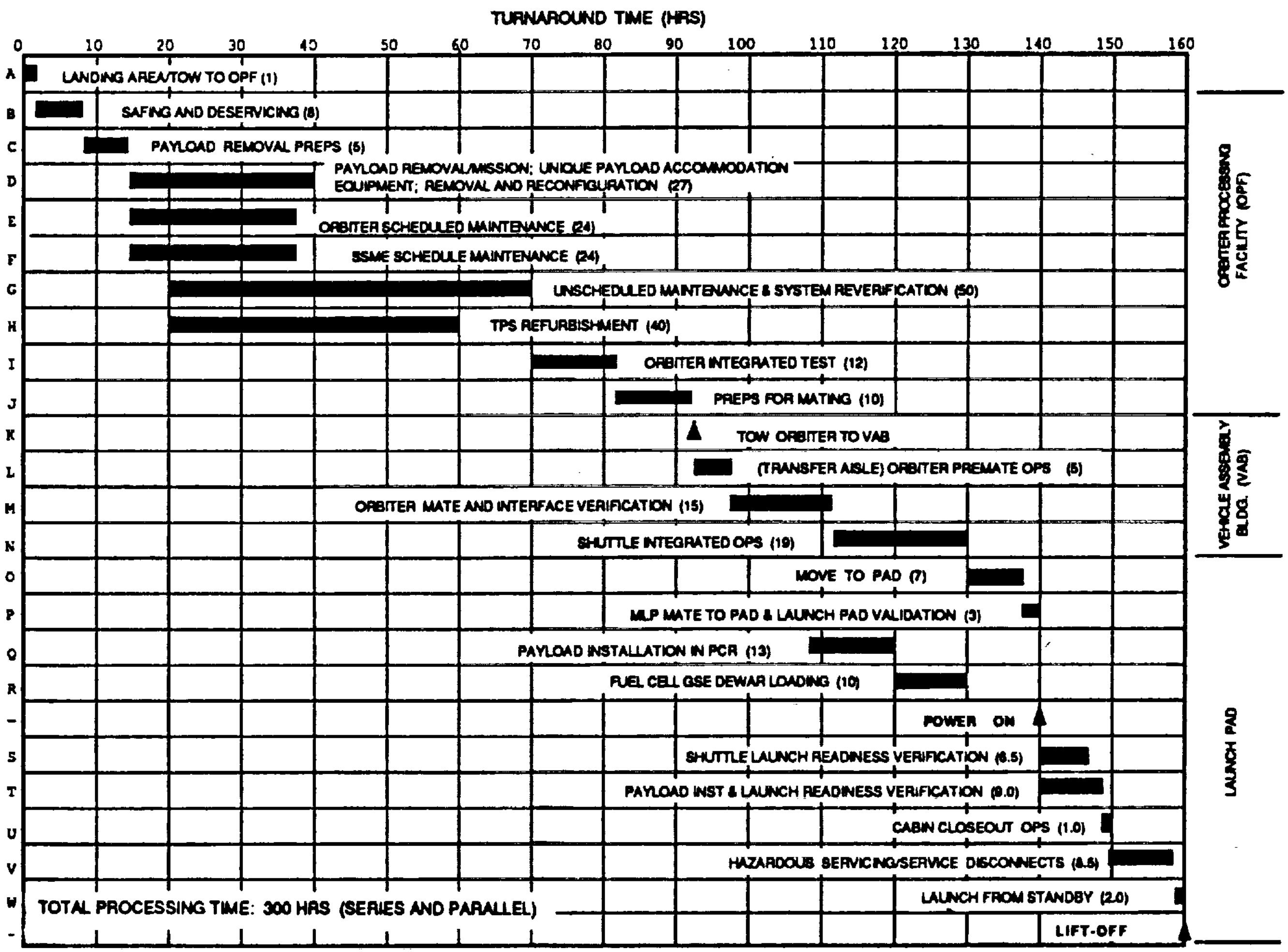
6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

This is a comparison between the 160 Hr Turnaround and the actual processing schedule for the 51-L Mission. This includes both the timelines and functon for the processing of the Orbiter from Roll-in in the OPF to launch.

Level I directed that the Shuttle be designed so that it could be launched with 160 working hours after the landing mission. This would be on a two shift workday, five days a week. Level II then divided this time into time to be spent in the OPF, VAB and at the pad. All designs were to support these requirements but due to both money and weight constraints, design compromises were made that lengthened the operational timelines considerable. Attached is the original Level II schedule with the time allotted to perform each task.

The following sheets give each task with the actual operations required; by the ORMSD and equipment failure, repair and retest; to process 51-L. The hours are the schedule hours required to perform each of the operations. Where possible the tasks were accomplished in parallel so that the total time does not correlate direcdtly with the original timelines. Also the tasks have been divided and intermixed during the processing.



160-HR. TIMELINE ALLOCATION
(PAYLOAD INSTALLATION AT PAD)
Figure 2

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6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

SUMMARY

The following summarized the results of this timeline analysis. They are:

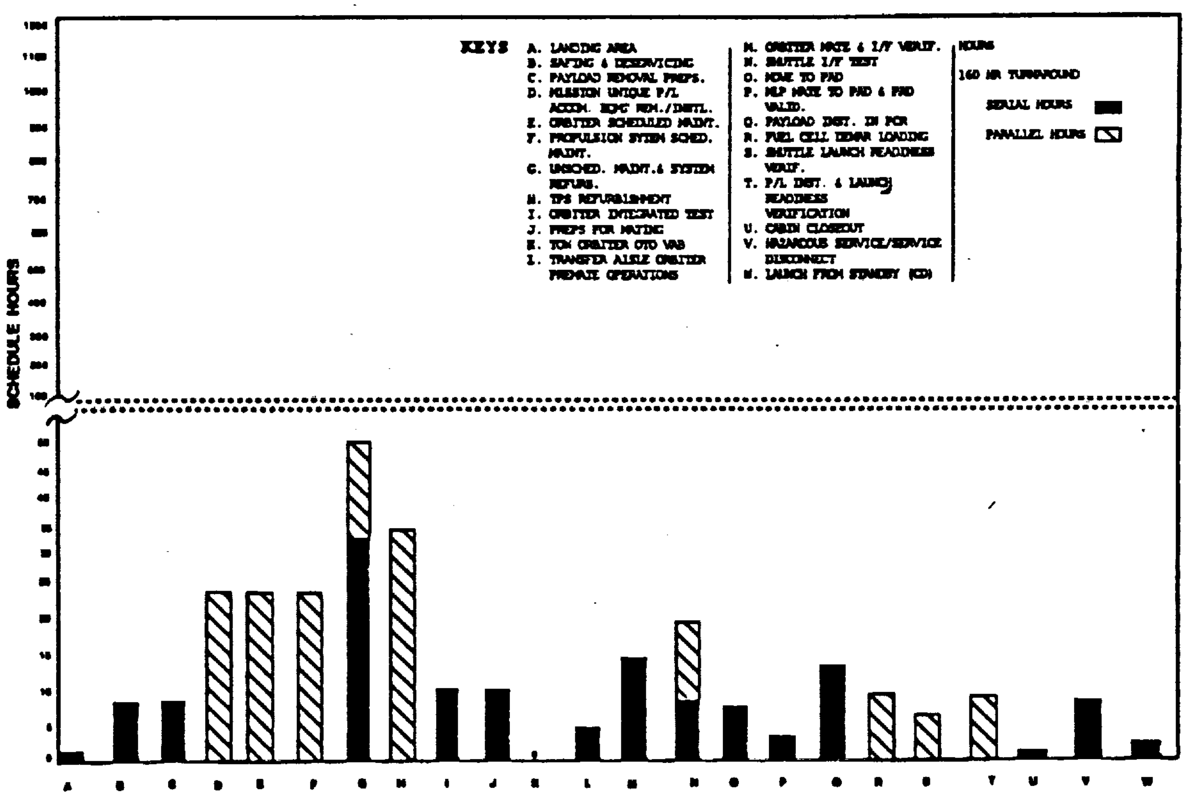
1. A comparison of the allocated 160-hour timelines (in 24 categories) of the actual time required to complete all the tasks included under each of these categories for the 51-L flow (preceding list).

2. A chart showing the time allotted in the 160-hour Turnaround Ground Operations Plan broken down into serial and parallel operations. (Figure 3)

3. The 51-L As-Run Schedule with tasks included under the different categories of the 160-hour turnaround broken down into serial and parallel operations. (Figure 4)

4. A comparison of the 160-hour timelines vs. the 51-L operations, per 160-hour categories, showing both serial and parallel operations. (Figure 5)

The analyses summarized on Figures 3 through 5 served to highlight the operations timeline growth by procedural / hardware areas. This enabled selection of high potential savings areas aby OMI.



160-HOUR TURNAROUND TIMELINE ALLOCATIONS
Figure 3

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

A. LANDING AREA 1.0 HR.

WAD	TITLE	HRS
V5001	SLF OPS/TOW TO OPF*	10.5

		10.5 hours total

* Previous mission landed at dfrf and was ferried to KSC on the SCA.

B. SAFING AND DESERVICING 8.0 HRS.

WAD	TITLE		HRS
V5001	TOW ORB INTO OPF/JACK & LEVEL/POWER UP PREPS		17.5
V1184	SAFING PATCHES/LOAD MMU		3.0
V1091	PRSD CRYO VENT		40.0
V1158	OMS TRICKLE PURGE & OMS/RCS DESERVICING		96.0
V5012	NOSE LANDING GEAR THRUSTER REMOVAL		8.0
V5012	PYRO WIRE HARNESS R&R RESISTANCE CHECK		48.0
V1078	APU LUBE OIL DESERVICING		24.0
N/A	MPS/SSME PROCESSING (ENGINE DRYING)		71.0
V1018	WATER SPRAY BOILER DESERVICING		24.0
VII96	APU POST FLIGHT FUEL SYSTEM OPS		85.0

		TOTAL	416.5

C. PAYLOAD REMOVAL PREPS. 5.0 HRS.

WAD	TITLE		HRS
V3512	INSTALL PAYLOAD ACCESS		8.0
V5006	PAYLOAD STRONGBACK INST/OPEN PAYLOAD BAY DOORS		17.0

		TOTAL	25.0

D. MISSION UNIQUE PAYLOAD ACCOMMODATION EQUIPMENT REMOVAL/INST. 27.0 HRS.

WAD	TITLE		HRS
N/A	AFT FLIGHT DECK/PAYLOAD BAY DECONFIG/RECONFIG.		240.0
V1175	RMS TURNAROUND VERIF.		16.0
V5R03	PRSD H2/O2 TANK SET 4 REMOVAL		120.0
N/A	PCP/CIU INSTALLATION		48.0
N0533	PCP/CIU CHECKOUT		5.5

		TOTAL	429.5

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

E. ORBITER SCHEDULED MAINTENANCE 24.0 HRS.

WAD	TITLE	HRS
V6002	ORBITER POST FLIGHT INSPECTION	24.0
V1026	REMOVE WASH & WASTE FUNCTIONAL	16.0
V5017	DESTOW FCE	16.0
V1084	CAUTION & WARNING SYS VERIFICATION	8.0
V5056	REMOVE GAS SAMPLE BOTTLES	8.0
V1134	WATER DRAIN (HORIZONTAL POSITION)	8.0
V1007	PV&D VENT FILTER/INSTL.	104.5
V1076	WCCS FUNCTIONAL CHECKS	176.0
V1062	AIR DATA SYSTEM	8.0
V1008	MSBLS TESTING	8.0
V1200	RECORDER DUMP	8.0
V6005	STARTRACKER CLEAN/INSPECT	8.0
V6018	CABIN AIR/RECIRCULATE MAINTENANCE	120.0
V6012	HYD INSPECTION	16.0
V1217	ECLSS ARPCS FUNCTIONAL TEST	12.0
V1178	KU BAND TURNAROUND C/O	8.0
V1184	LOAD MMU	12.0
V1005	VTR C/O	4.0
V1086	MEC PIC TEST	44.0
V5069	TRANSFER TO AFT 999 JACKS	3.0
V1016	VENT DOOR FUNCTIONAL	11.0
V1097	ET DOOR FUNCTIONAL/LATCH FOR FLIGHT	8.0
V5069	TRANSFER TO AFT 570 JACKS	3.0
V1026	REMOVE WASTE COLLECTION SYSTEM & WASTE FLUSH	24.0
V1153	APU WATER SERVICING	48.0
V1099	STARTRACKER DOOR FUNCTIONAL	5.0
V1042	SMOKE DETECTION & FIRE SUPPERSSION FUNCTIONAL	4.0
V5010	INSTALL B/C/ELBOW CCTV	8.0
V1003	POWER SYSTEM VALIDATION	23.0
V1180	FRCS FUNCTIONAL C/O (LPS)	14.0
V1080	MULT CRT DISP SYS C/O (LPS)	4.0
V1098	LANDING GEAR FUNCTIONAL	4.0
V6034	CREW MODULE SEAT FUNCTIONAL	8.0
V1005	CCTV SYSTEM TEST	3.0
V1183	ORBITER ELECTRICAL SYSTEM VALIDATION (LPS)	12.0
V1078	APU LUBE OIL SERVICING	66.0
V1041	N2 SERVICING	8.0
V9023	CLOSE/OPEN PAYLOAD BAY DOORS	11.0
V1180	AFT OMS/RCS FUNCTIONAL	96.0
V1037	NH3 SYSTEM SERVICING	24.0
V1055	POTABLE WATER SERVICING	24.5
V1017	WATER SPRAY BOILER SYSTEM LEAK & FUNCTIONAL	25.0
V9002	BRAKE FILL & BLEED	4.0
V1048	NOSE WHEEL STEERING	5.0
V1065	BRAKE/ANTI-SKID CONTROL SYSTEM TEST (LPS)	8.0
V1060	AEROSURFACE CHECKOUT	5.5
V6034	GALLEY FUNCTIONAL	8.0
V5050	FLIGHT CREW EQUIPMENT STOWAGE/CEIT/DESTOWAGE	19.0
TPS	FLIGHT CREW EQUIPMENT INFLIGHT MAINT. WALKDOWN	3.0
V9001	STOW KU BAND ANTENNA	8.0
V1131	HYDRAULIC ACCUMULATOR CHECKS	8.0
V1161	ORBITER BUSS REDUNDANCY	19.0
	TOTAL	1132.5

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

F. PROPULSION SYSTEM SCHEDULED MAINTENANCE 24.0 HRS.

WAD	TITLE		HRS
V9002	HYDRAULIC POWER UP PREPS & POSITION SSME'S		49.0
V5043	REMOVE HEAT SHIELDS		20.0
V1009	MPS LEAK & FUNCTIONAL		176.0
V1011	SSME LEAK & FUNCTIONAL		176.0
V5058	REMOVE SSME #2		5.5
TPS	NOZZLE WELD INSPECTION (VAB)	*	240.0
V5E06	SSME #1 HIGH PRESSURE FUEL TURBOPUMP R&R		37.0
V5E06	SSME #2 HIGH PRESSURE FUEL TURBOPUMP R&R (VAB)	*	40.0
V5E29	SSME #2 GIMBAL BOLT R&R	*	32.0
V5057	DISCONNECT SSME TVC'S/INSTALL STIFF ARMS		4.0
V5005	INSTALL SSME #2		20.0
V1063	SSME TVC FLIGHT CONTROLS		3.0
V1011	SSME FLIGHT READINESS TEST		13.0
V1001	SSME ELECTRICAL INTERFACE VERIFICATION		8.0
V9019	MPS VJ LINES CHECK		4.0
V5057	REMOVE STIFF ARMS/CONNECT SSME TVC'S		8.0
V5043	HEAT SHIELD INSTALLATION		57.5
		TOTAL	893.0

* These operations were accomplished in the engine shop in the VAB.

G. UNSCHEDULED MAINTENANCE & SYSTEM REVERIFICATION 50.0 HRS.

WAD	TITLE	HRS
N5230	ORBITER POST FLIGHT TROUBLESHOOTING	64.0
V1053	REMOVE CABIN SENSOR	8.0
V7253	WINDOW POLISHING	112.0
N/A	ORBITER POST FLIGHT TROUBLESHOOTING	32.0
IPR	TANK #1 H2 CRYO CONTROL HEATER TROUBLESHOOTING	48.0
V5R01	FUEL CELL #1 REMOVAL	64.0
IPR	MSBLS TROUBLESHOOTING	3.0
PR	REMOVE MSBLS	1.0
V1165	LANDING/BRAKE INSTALLATION	24.0
PR	R&R LAUNCH CONTROL AMPLIFIER	3.0
V5U01	REMOVE APU #3	31.0
V5011	R&R RH OMS POD	29.0
V5079	OMS ENGINE HEAT SHIELD REMOVAL	16.0
V1164	ELEVON LOWER COVE SEAL PRESS LEAK RATE	24.0
V5U01	REINSTALL APU #3	16.0
V5016	TRANSFER RIGHTHAND OMS POD TO HMF	2.0
PR	R&R HEADS UP DISPLAY UNIT	8.0
TPS	AMMONIA TANK PURGE	16.0
V1165	LANDING GEAR BRAKE INSPECTION & BRAKE R&R	23.0
TPS	NH3 LEAK & FUNCTIONAL	16.0
V1225	RIGHT OMS INTERFACE TEST	32.0
V5R01	INSTALL FUEL CELL #1	11.5
V1165	INSTALL NOSE LANDING GEAR TIRES	8.0
V1177	HEADS UP DISPLAY CHECKOUT	3.0

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

G. UNSCHEDULED MAINTENANCE & SYSTEM REVERIFICATION (Continued)

TPS	MATE APU FUEL LINES	13.0
IPR	LEAK IN APU FUEL LINE "B"NUT	16.0
V5079	LEFTHAND OMS ENGINE HEAT SHIELD INST'L R/T & LK CK	16.0
V1180	AFT OMS/RCS FUNCTIONAL	4.0
PR	INSTALL THRUSTER & RETEST	8.5
V1226	OMS POD MATING	16.0
V1053	CABIN SENSOR INSTALLATION & RETEST	8.0
IPR	REMOVE BREAK OUT BOXES	2.0
PR	LEFT OMS CROSSFEED LINE PROBLEM	22.5
V5011	R&R LEFTHAND OMS POD	26.5
V1224	OMS POD ELECTRICAL CONNECT & RETEST	12.5
V1226	LEFTHAND OMS CROSSFEED CONNECT	5.0
V1161	BUSS REDUNDANCY LEFTHAND OMS POD	9.0
	TOTAL	753.5

H. TPS REFURBISHMENT 40.0 HRS.

WAD	TITLE	HRS
V6028	ORBITER POST FLIGHT TPS INSPECTION	N/A
V9024	ORBITER TPS MAINTENANCE/OPERATION	N/A
N/A	ORBITER TPS WATERPROOFING	N/A
V9022	ET DOOR CYCLES/TPS OPERATIONS	120.0
V6035	RSI PRE ROLLOUT INSP & UPPER SURFACE WATERPROOFING	71.0
	TOTAL	191.0+

NOTE: The 51-L as-run schedule shows the first three above operations starting as soon as the orbiter is rolled into the OPF but does not identify how long they continue. The STS-XX schedule allows 60 hrs. for both the inspection and the maintenance operation and the 168 hrs. for waterproofing.

I. ORBITER INTEGRATED TEST 10.0 HRS.

NOTE: The requirement for this test has been deleted from the OMRSD.

J. PREPS FOR MATING 12.0 HRS.

WAD	TITLE	HRS
V5012	AFT SEP HARNESS/ET UMB GSE & PLUG INSTALLATION	8.0
V5012	FWD ET BEARING & YOKE INSTALLATION	32.0
V5012	PRE-OPS SET UP	16.0
V5012	POWER DOWN ORDNANCE INSTALLATION	8.0

J. PREPS FOR MATING (Continued)

V5012	POWER ON PIC TEST	8.0
V6034	PAYLOAD BAY SHARP EDGE INSPECTION	4.0
V1032	ORBITER CLOSEOUT	104.0
V1032	ORBITER AFT CLOSEOUT	85.5
V6003	PAYLOAD BAY CLOSEOUT/INSPECTION	20.0
V9021	DEACTIVATE TRICKLE PURGE	8.0
V1176	PAYLOAD BAY CLEANING	27.5
V5018	CLOSE PAYLOAD BAY DOORS & REMOVE STRONGBACKS	16.0
V9002	HYD OPS/POSITION AEROSURFACES FOR ROLLOUT	4.5
V3555	DISCONNECT ORBITER PURGE AIR	5.0
V3515	R5.0 EMOVE LH2/LO2 CARRIER PLATES	5.0
V5101	J5.0 ACKDOWN WEIGH & CG/PREP TO TOW	8.0
	TOTAL	359.5

K. TOW ORBITER TO VAB NO TIME ALLOTTED

WAD	TITLE	HRS
S0004	ORBITER TOW & MATE	.5
	TOTAL	.5

L. TRANSFER AISLE ORBITER PREMATE OPS 5.0 HRS.

WAD	TITLE	HRS
S0004	ORBITER TOW & MATE	18.5
	TOTAL	18.5

M. ORBITER MATE AND INTERFACE VERIFICATION 15.0 HRS.

WAD	TITLE	HRS
S0004	ORBITER TOW & MATE	103.0
SOOO8	SHUTTLE INTERFACE VERIFICATION	36.5
S0020	SRB TESTING	5.5
	TOTAL	144.0

N. SHUTTLE INTERFACE TEST 19.0 HRS.

NOTE: The requirements for this tet have been removed from the OMR and is no longer being accomplished.

O. MOVE TO PAD 7.0 HRS.

WAD	TITLE	HRS
A5214	TRANSFER & MATE TO PAD B	13.5
	TOTAL	13.5

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

P. MLP MATE TO PAD & LAUNCH PAD VALIDATION 3.0 HRS.

WAD	TITLE		HRS
S0009	LAUNCH PAD VALIDATION		9.5
N/A	POWER UP PREPS		30.0
		TOTAL	39.5

Q. PAYLOAD INSTALLATION IN PCR 13.0 HRS.

WAD	TITLE		HRS
NO133	CARGO INSTALLATION IN PCR PAD B		35.5
N/A	WIND DELAY IN INSTALLING CARGO IN PCR		33.0
N/A	IUS SCU PROBLEM		32.5
N1533	TDRS PROPELLANT LOAD		33.5
N/A	IUS POWER UP/DOWN TEST		21.5
N/A	IUS STANDALONE TEST		18.0
		TOTAL	174.0

R. FUEL CELL DEWAR LOADING 10.0 HRS.

WAD	TITLE		HRS
V2303	DEWAR LOAD		6.5
		TOTAL	6.5

NOTE: The 160 hr. Turnaround Schedule has this activity to occur prior to the arrive of the vehicle at the pad. During the 51-L flow, it was accomplished just prior to hyper load which caused another pad clear operation in the pad operation.

S. SHUTTLE LAUNCH READINESS VERIFICATION 6.5 HRS.

WAD	TITLE		HRS
S0009	LAUNCH PAD VALIDATION WITH APU HOT FIRE *		40.0
V1202	HE SIGNATURE TEST		17.5
		TOTAL	57.5

* This time includes 4.5 hrs for emergency power down if the orbiter cooling was lost to the vehicle.

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

T. PAYLOAD INSTALLATION & LAUNCH READINESS VERIFICATION 90 HRS

WAD	TITLE	HRS
N0133	CARGO PAYLOAD BAY OPERATIONS	80.0
S0017	TERMINAL COUNT DEMONSTRATION TEST	55.5
V9023	OPEN PAYLOAD BAY DOORS	1.5
S0009	1ST MOTION CHECKS & SRSS HOLDFIRE CHECKS	6.0
N/A	HOT GAS SYSTEM TROUBLESHOOTING	15.0
V1202	HOT GAS POI'S	7.5
V1149	AFT CAVITY PURGE	9.5
PR	PDI R&R AND RETEST	5.0
B1500	R&R SRB AFT IEA	8.5
N0433	IUS TDRS IVT/ETE	25.0
IPR	R&R HIM 6893	2.5
PR	IEA ELECTRICAL CONNECT & RETEST	12.5
N/A	POD TOTALIZER CONNECT & RETEST	13.0
PR	UPS 40 TROUBLESHOOTING/CARD CHANGE/RETEST	8.5
N/A	CHARGE CARGO BATTERIES	15.5
V1077	FUEL CELL #1 SERVICING	8.0
	TOTAL	273.5

U. CABIN CLOSEOUT 1.0 HR.

NOTE: No serial time was allotted during the pad operations to closeout the crew cabin prior to the propellant loading.

V. HAZARDOUS SERVICING/SERVICE DISCONNECTS 8.5 HRS.

WAD	TITLE	HRS
S0024	PRE LAUNCH PROPELLANT LOAD	202.5
T1401	ET BLANKING PLATE REMOVAL	5.5
N/A	PAYLOAD DISCONNECT/ PLB CLOSEOUT/PLB DOORS CLOSE	7.0
PR	R&R RJDA #2 & RETEST	9.5
PR	R&R QD & RETEST OMS REG. LOCK UP TEST	8.0
S0009	ORDNANCE INSTALLATION	37.0
N/A	CARRIER PANEL INSTALLATION	37.0
S5009	ORBITER AFT CLOSEOUT	75.0
S1005	ET PURGES	12.0

The following operations were preformed during this block of time but were part of the original timelines.

N/A	CARGO STANDALONE OPS	88.0
V1103	EMU INSTALLATION & TEST	16.0
V9002	SSME VALVE CYCLES/FRT'S	32.0
V1184	MMU FLIGHT LOAD	14.0
	TOTAL	543.5

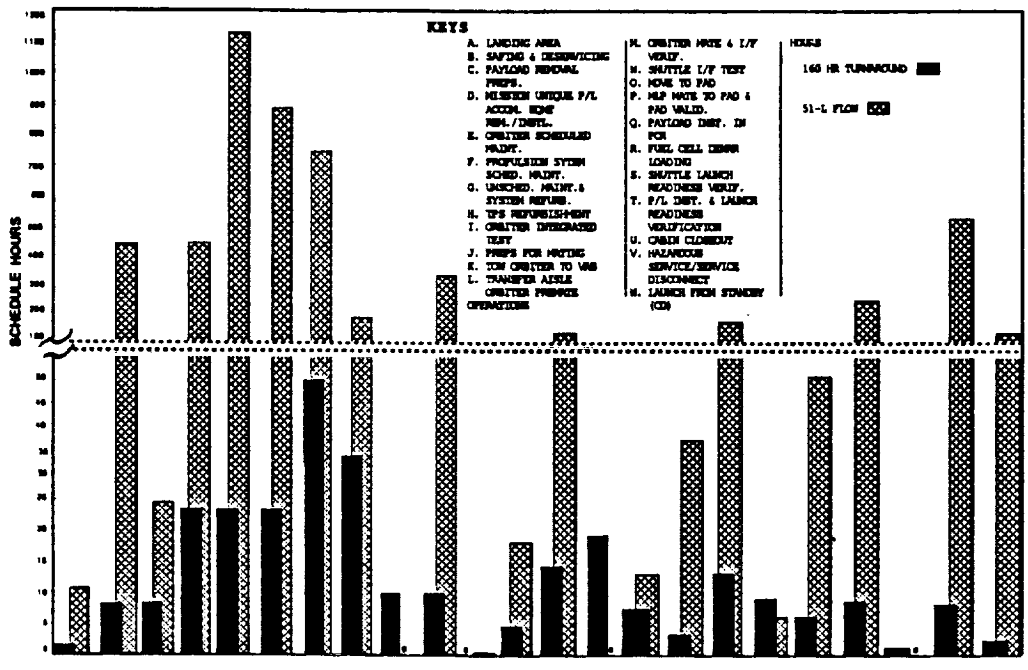
W. LAUNCH FROM STANDBY 2.0 HRS.

WAD	TITLE	HRS
S0007	LAUNCH COUNTDOWN	121.5
	TOTAL	121.5

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS

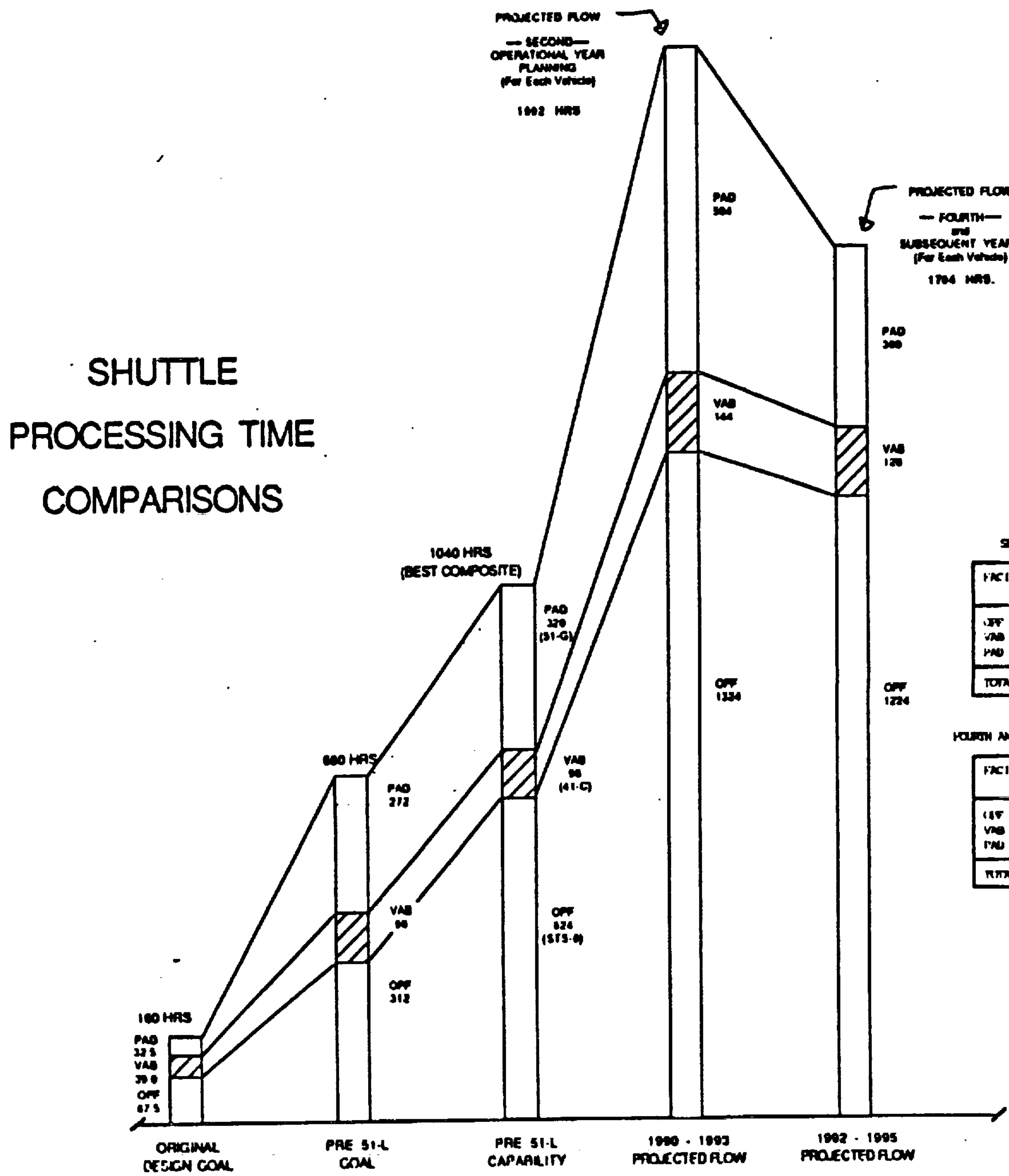
NOTE: The length of the countdown for the 51-l mission was much longer due to several delays caused mainly by weather. The first one was bad visibility at the transatlantic landing site (dust storm in North Africa). Possible adverse weather at the launch site then caused a 24 hour delay, and on the third attempt, high cross winds caused a scrub at T-9 minutes. A normal countdown is now scheduled for 56 hours.

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS



160-HOUR TURNAROUND vs. 51-L AS-RUN SCHEDULE
MAJOR OPERATIONS ACTIVITY
Figure 4

6.5.4 STS 160-HR. TURNAROUND VS. 51-L ACTUALS



SECOND OPERATIONAL YEAR PLANNING

FACIL	WORK DAYS	DAYS/SHIFTS	HOURS
OFF	56 DAYS	7/3	1344
VAB	6 DAYS	7/3	144
PAD	21 DAYS	6/3	504
TOTAL	83 DAYS	249 SHIFTS	1992

FOURTH AND SUBSEQUENT OPERATIONAL YEAR PLANNING

FACIL	WORK DAYS	DAYS/SHIFTS	HOURS
OFF	51 DAYS	7/3	1224
VAB	5 DAYS	7/3	120
PAD	15 DAYS	6/3	360
TOTAL	71 DAYS	213 SHIFTS	1704

160-HR TIMELINES VS. 51-L OPERATIONS
Figure 5

OPF SSME PROCESSING TIME

Ref: Rocketdyne Division Pocket Data
RI/RD87-142, May 1987

	FLIGHT	DATE	ORBITER	OPF PROCESSING TIME, SHIFTS
1.	STS-1	4/12/81	102	N/A (COLUMBIA)
2.	STS-2	11/12/81	102	144
3.	STS-3	3/22/82	102	57
4.	STS-4	6/27/82	102	66
5.	STS-5	11/11/82	102	63
6.	STS-6	4/4/83	99	N/A (CHALLENGER)
7.	STS-7	6/18/83	99	52
8.	STS-8	8/30/83	99	24
9.	STS-9	11/28/83	102	N/A
10.	STS-11	2/3/84	99	43.5
11.	STS-13	4/6/84	99	30.5
12.	STS-14	8/30/84	103	N/A (DISCOVERY)
13.	STS-17	10/5/84	99	N/A
14.	STS-19	11/8/84	103	38
15.	STS-20	1/24/85	103	51
16.	STS-23	4/12/85	103	97
17.	STS-24	4/29/85	99	60
18.	STS-25	6/17/85	103	64
19.	STS-26	7/29/85	99	92
20.	STS-27	8/27/85	103	70
21.	STS-28	10/3/85	104	N/A (ATLANTIS)
22.	STS-30	10/30/85	99	102
23.	STS-31	11/26/85	104	58
24.	STS-32	1/12/86	102	65
25.	STS-33	1/28/86	99	71
			TOTAL:	1248

SUMMARY - N/A - 6 flights data not available

19 Flights average SSME process time - 65.7 shifts
maximum SSME process time - 144 shifts
minimum SSME process time - 24 shifts

4 flights required more than 71 shifts - (21%)
11 flights required from 50 to 71 shifts - (58%)
4 flights required less than 50 shifts - (21%)
The 11 "median" flights required an average of 61.5 shifts
which is equivalent to 20.5 3-shift days

CONCLUSION: Normal STS SSME OPF processing requires 3 weeks per launch

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6.5.5 SHUTTLE CONFIGURATION & FACILITIES DATA

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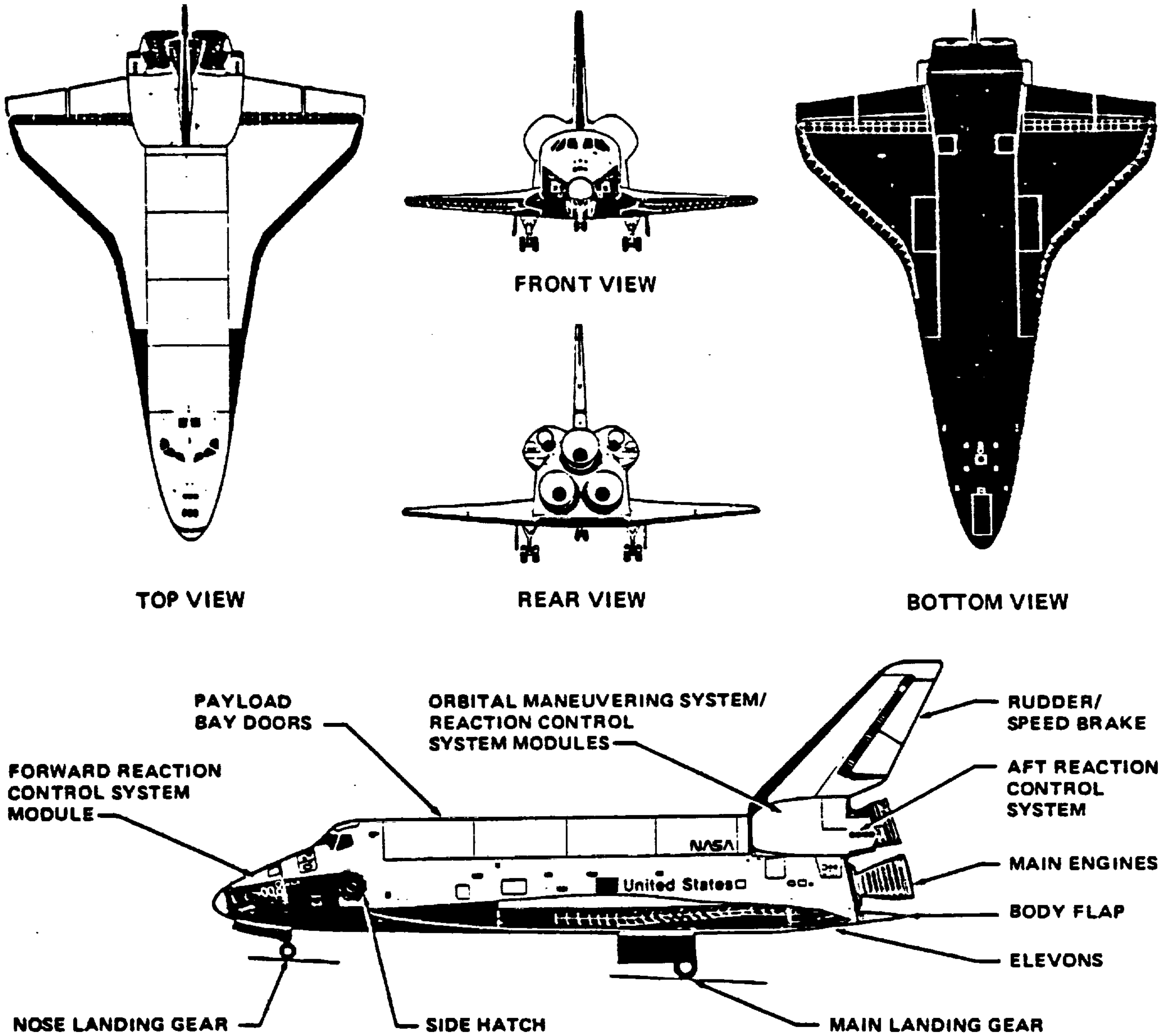
6.5.5 SHUTTLE CONFIGURATION & FACILITIES DATA



DIMENSIONS AND WEIGHT

WING SPAN	23.79 m	(78.06 FT)
LENGTH	37.24 m	(122.17 FT)
HEIGHT	17.25 m	(56.58 FT)
TREAD WIDTH	6.91 m	(22.67 FT)
GROSS TAKEOFF WEIGHT		VARIABLE
GROSS LANDING WEIGHT		VARIABLE
INERT WEIGHT (APPROX)	74 844 kg	(165 000 LB)

MINIMUM GROUND CLEARANCES

BODY FLAP (AFT END)	3.68 m	(12.07 FT)
MAIN GEAR (DOOR)	0.87 m	(2.85 FT)
NOSE GEAR (DOOR)	0.90 m	(2.95 FT)
WINGTIP	3.63 m	(11.92 FT)

Figure 1-3.— The Space Shuttle Orbiter.

Briefly . . .

The three main engines of the Space Shuttle, in conjunction with the Solid Rocket Boosters, provide the thrust to lift the Orbiter off the ground for the initial ascent. The main engines operate for approximately the first 8.5 minutes of flight.

THRUST
Sea level: 1670 kilonewtons (375 000 pounds)

Vacuum: 2100 kilonewtons (470 000 pounds)

(Note: Thrust given at rated or 100-percent power level.)

THROTTLING ABILITY
65 to 109 percent of rated power level

SPECIFIC IMPULSE
Sea level: 356.2 $\frac{N/s}{kg}$ $\left(363.2\ \frac{lbf/s}{lbm}\right)$

Vacuum: 4464 $\frac{N/s}{kg}$ $\left(455.2\ \frac{lbf/s}{lbm}\right)$

(Given in newtons per second to kilograms of propellant and pounds-force per second to pounds-mass of propellant)

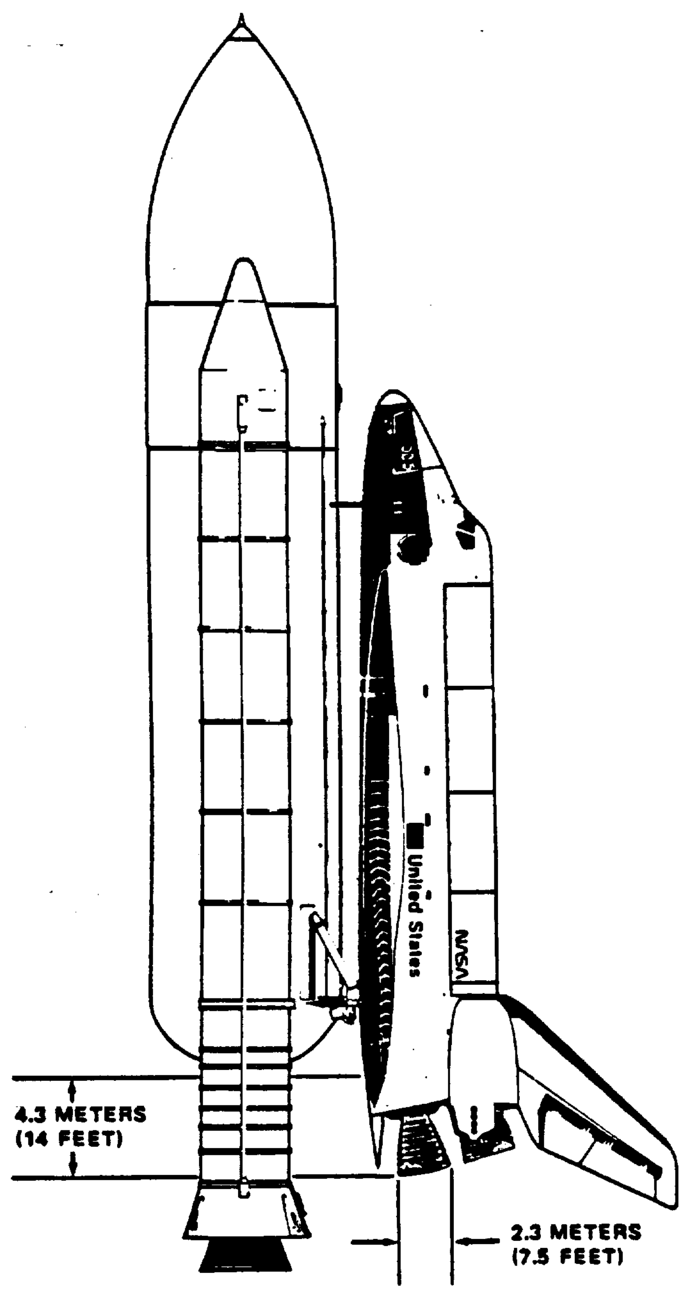
CHAMBER PRESSURE
20 480 kN/m^2 (2970 psia)

MIXTURE RATIO
6 parts liquid oxygen to 1 part liquid hydrogen (by weight)

AREA RATIO
Nozzle exit to throat area 77.5 to 1

WEIGHT
Approximately 3000 kilograms (6700 pounds)

LIFE
7.5 hours, 55 starts



Briefly . . .

The Solid Rocket Boosters operate in parallel with the main engines for the first 2 minutes of flight to provide the additional thrust needed for the Orbiter to escape the gravitational pull of the Earth. At an altitude of approximately 45 kilometers (24 nautical miles), the SRB's separate from the Orbiter/External Tank, descend on parachutes, and land in the Atlantic Ocean. They are recovered by ships, returned to land, and refurbished for reuse.

STATISTICS FOR EACH BOOSTER

THRUST AT LIFT-OFF
11 790 kilonewtons (2 650 000 pounds)

PROPELLANT
Atomized aluminum powder (fuel), 16 percent

Ammonium perchlorate (oxidizer), 69.83 percent

Iron oxide powder (catalyst), 0.17 percent (varies)

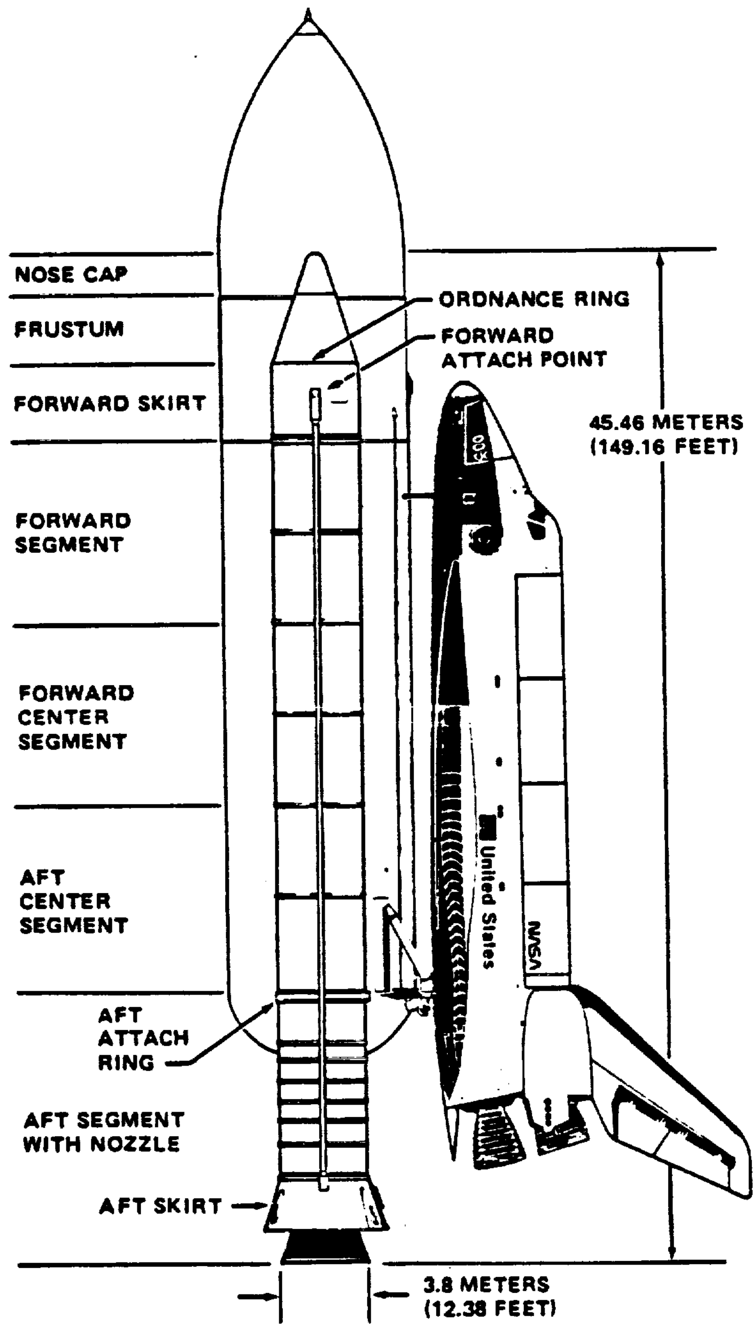
Polybutadiene acrylic acid acrylonitrile (binder), 12 percent
Epoxy curing agent, 2 percent

WEIGHT

Empty:	87 550 kilograms (193 000 pounds)
Propellant:	502 125 kilograms (1 107 000 pounds)
Gross:	589 670 kilograms (1 300 000 pounds)

THRUST OF BOTH BOOSTERS AT LIFT-OFF
23 575 kilonewtons (5 300 000 pounds)

GROSS WEIGHT OF BOTH BOOSTERS AT LIFT-OFF
1 179 340 kilograms (2 600 000 pounds)



Briefly . . .

The External Tank is the "gas tank" for the Orbiter; it contains the propellants used by the main engines. Approximately 8.5 minutes into the flight with most of its propellant used, the ET is jettisoned and splashes down in the Indian Ocean. It is the only major part of the Space Shuttle system that is not reused.

TOTAL WEIGHT

Empty:	35 425 kilograms (78 100 pounds)
Gross:	756 441 kilograms (1 667 677 pounds)

PROPELLANT WEIGHT

Liquid oxygen:	616 493 kilograms (1 359 142 pounds)
Liquid hydrogen:	102 618 kilograms (226 237 pounds)
Total:	719 112 kilograms (1 585 379 pounds)

PROPELLANT VOLUME

Liquid oxygen tank:	541 482 liters (143 060 gallons)
Liquid hydrogen tank:	1 449 905 liters (383 066 gallons)
Total:	1 991 387 liters (526 126 gallons)

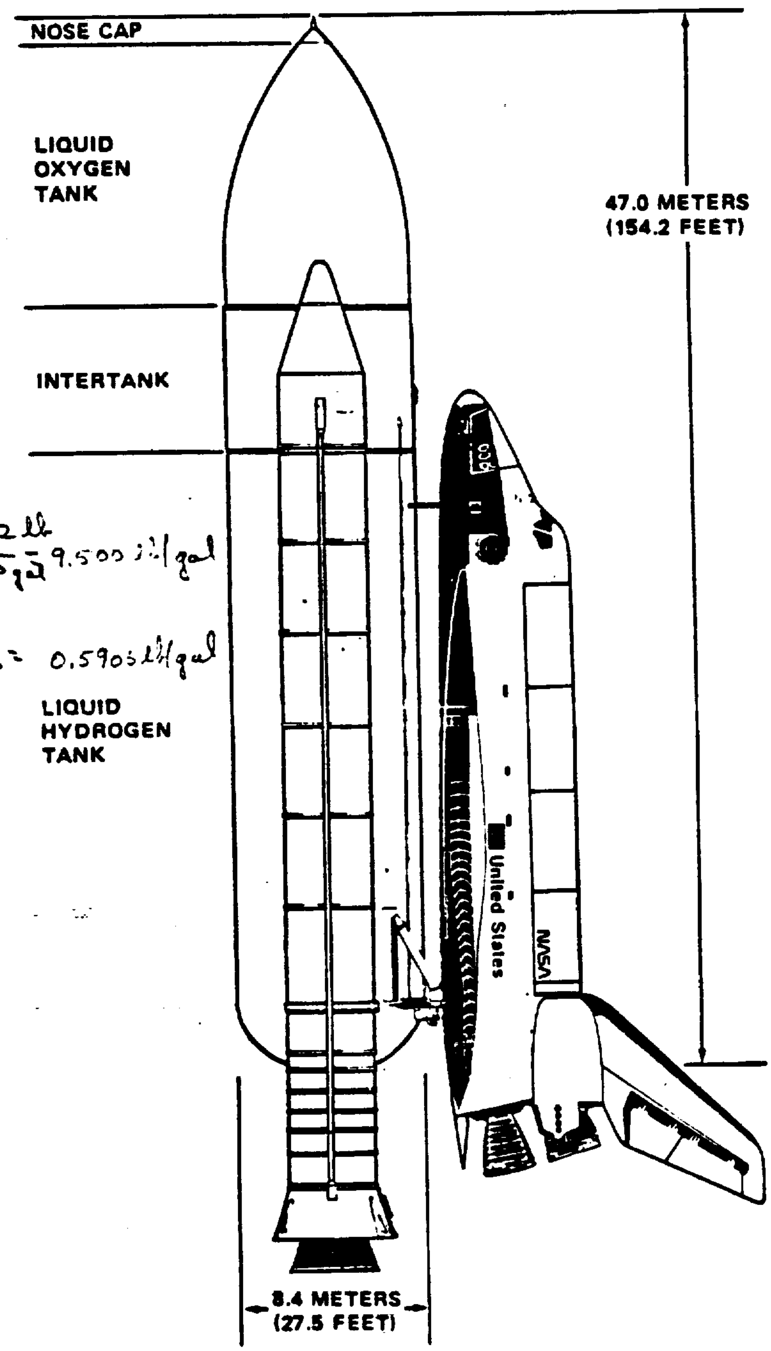
$\frac{1359,142\ lb}{143,060\ gal} = 9.500\ lb/gal$

$\frac{226,237}{383,066} = 0.5905\ lb/gal$

(Propellant densities of 1138 and 70.8 kg/m³ (71.07 and 4.42 lb/ft³) used for liquid oxygen and liquid hydrogen, respectively)

DIMENSIONS

Liquid oxygen tank:	16.3 meters (53.5 feet)
Liquid hydrogen tank:	29.6 meters (97 feet)
Intertank:	6.9 meters (22.5 feet)



Briefly . . .

The cockpit, living quarters, and experiment operator's station are located in the forward fuselage of the Orbiter vehicle. Payloads are carried in the mid-fuselage payload bay, and the Orbiter's main engines and maneuvering thrusters are located in the aft fuselage.

TOTAL LENGTH
37.24 meters (122.17 feet)

HEIGHT
17.25 meters (56.58 feet)

VERTICAL STABILIZER
8.01 meters (26.31 feet)

WINGSPAN
23.79 meters (78.06 feet)

BODY FLAP
12.6 square meter (135.8 square foot) area
6.1 meters (20 feet) wide

AFT FUSELAGE
5.5 meters (18 feet) long
6.7 meters (22 feet) wide
6.1 meters (20 feet) high

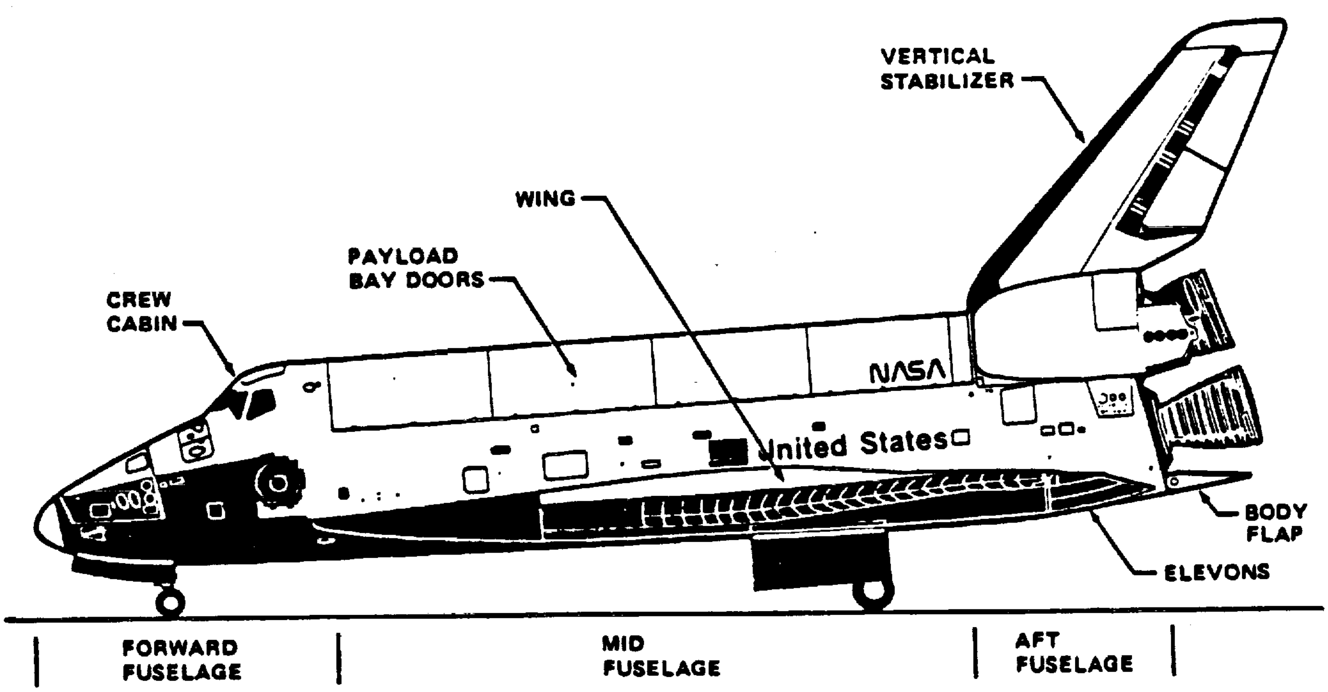
MID FUSELAGE
18.3 meters (60 feet) long
5.2 meters (17 feet) wide
4.0 meters (13 feet) high

FORWARD FUSELAGE
CREW CABIN
71.5 cubic meters (2525 cubic foot) volume

PAYLOAD BAY DOORS
18.3 meters (60 feet) long
4.6 meters (15 feet) in diameter
148.6 square meters (1600 square feet) surface area

WING
18.3 meters (60 feet) long
1.5 meter (5 foot) maximum thickness

ELEVONS
4.2 meters (13.8 feet)
3.8 meters (12.4 feet)



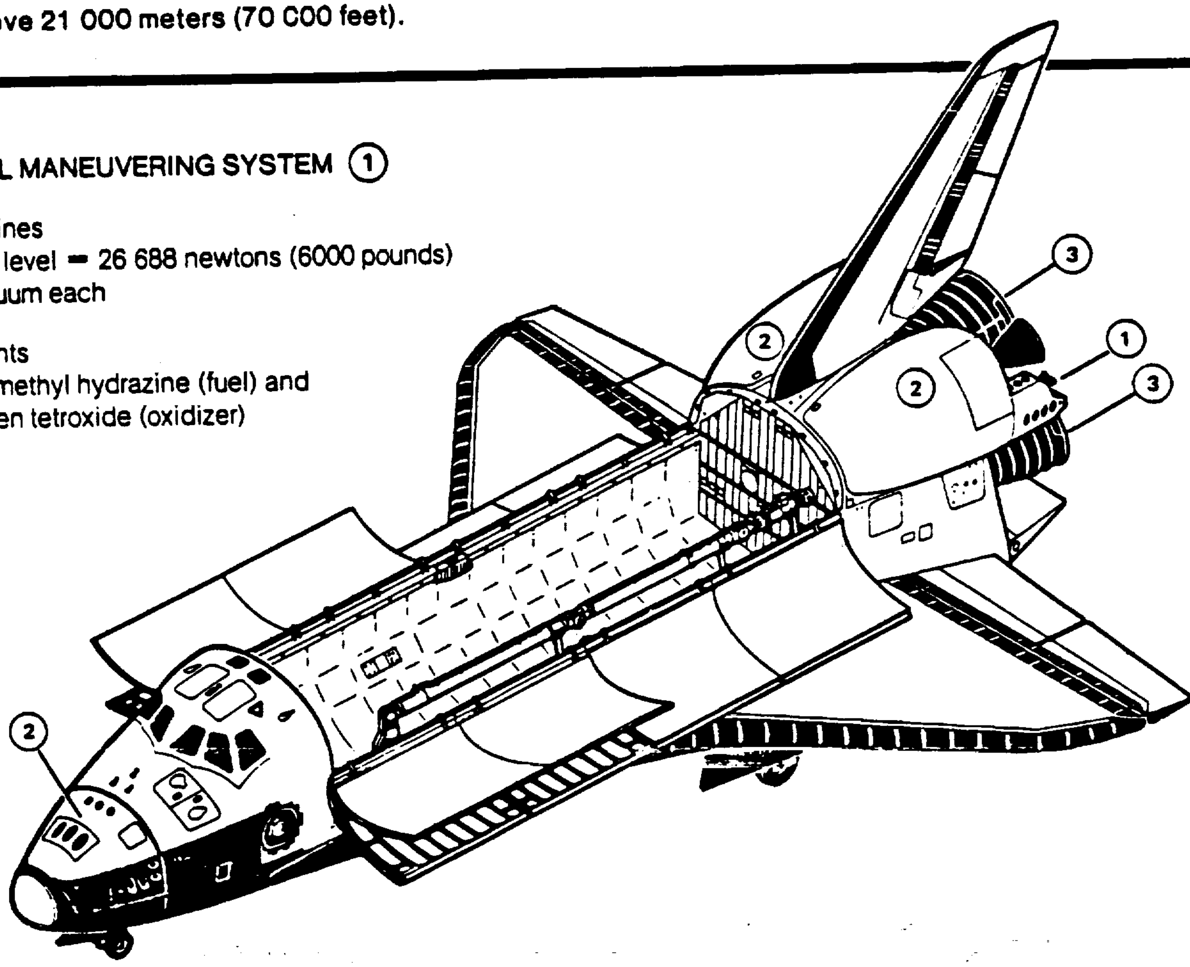
Briefly . . .

The propulsion systems of the Space Shuttle consist of the three main engines, the Solid Rocket Boosters, and the External Tank (see section 2) and the orbital maneuvering and reaction control systems. The main engines and the boosters provide the thrust for the launch phase of the mission. The orbital maneuvering system thrusts the Orbiter into orbit and provides the thrust to transfer from one orbit to another, to rendezvous with another spacecraft, and to deorbit. The reaction control system provides the power needed to change speed in orbit and to change the attitude (pitch, roll, or yaw) of the Orbiter when the vehicle is above 21 000 meters (70 000 feet).

ORBITAL MANEUVERING SYSTEM ①

Two engines
  Thrust level = 26 688 newtons (6000 pounds)
    vacuum each

Propellants
  Monomethyl hydrazine (fuel) and
  nitrogen tetroxide (oxidizer)



REACTION CONTROL SYSTEM ②

One forward module, two aft pods

38 primary thrusters (14 forward, 12 per aft pod)
  Thrust level = 3870 newtons (870 pounds)

Six vernier thrusters (two forward, four aft)
  Thrust level = 111.2 newtons (25 pounds)

Propellants

  Monomethyl hydrazine (fuel) and
  nitrogen tetroxide (oxidizer)

MAIN PROPULSION (See section 2) ③

Three engines
  Thrust level = 2 100 000 newtons (470 000 pounds)
    vacuum each

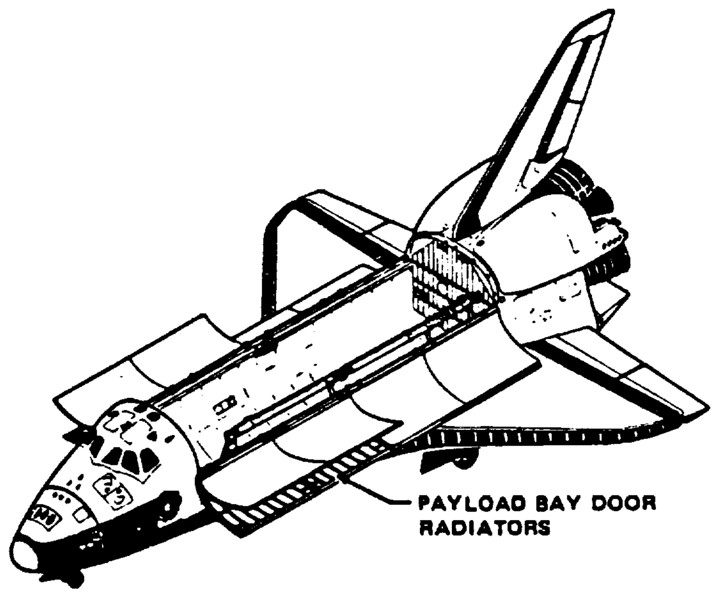
Propellants

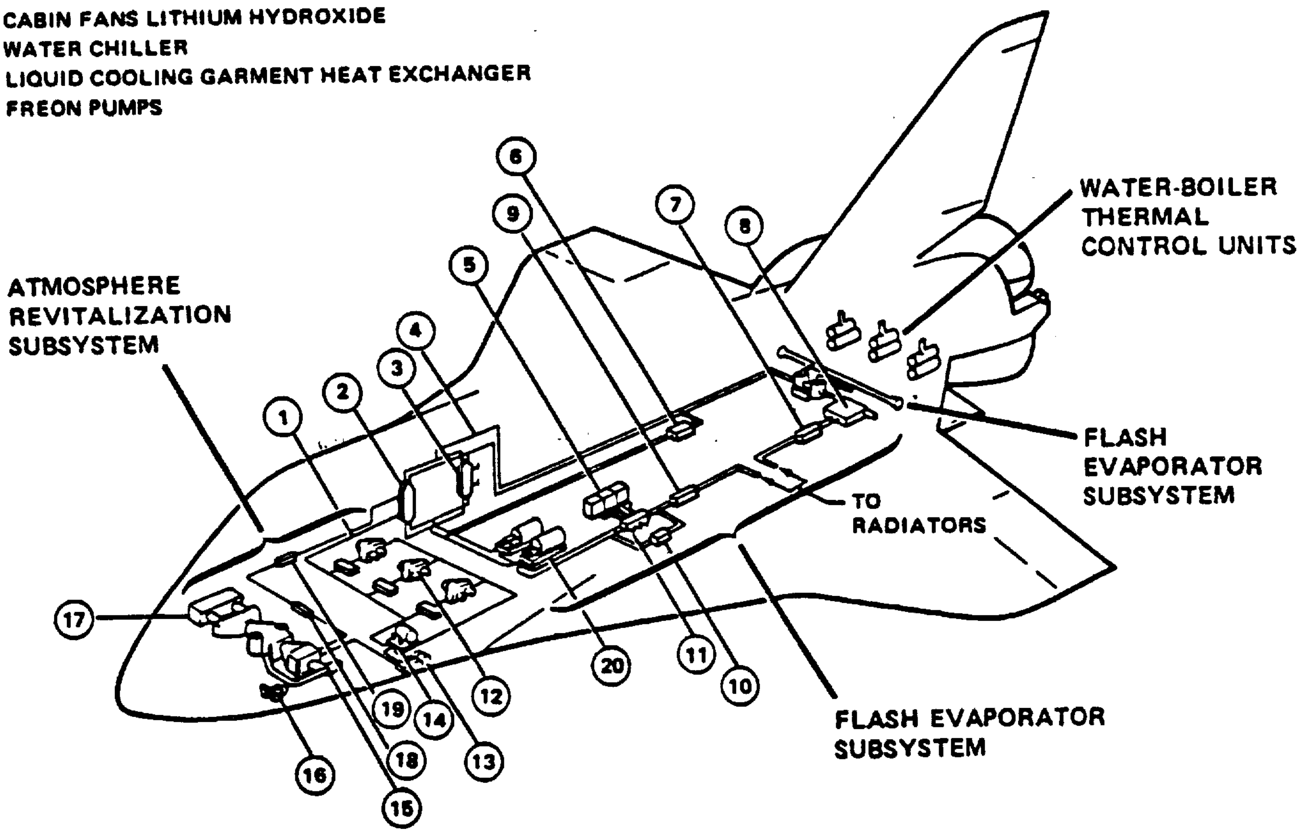
  Liquid hydrogen (fuel) and
  liquid oxygen (oxidizer)

Briefly . . .

The Orbiter's environmental control and life-support system scrubs the cabin air, adds fresh oxygen, keeps the pressure at sea level, heats and cools the air, and provides drinking and wash water and a toilet not too unlike the one at home.

1 WATER LOOP
2 INTERCHANGER HEAT EXCHANGER
3 PAYLOAD HEAT EXCHANGER
4 FREON LOOP
5 FUEL CELLS
6 AFT COLDPLATES
7 GROUND SUPPORT EQUIPMENT HEAT EXCHANGER
8 AMMONIA EVAPORATOR
9 HYDRAULIC HEAT EXCHANGER
10 MID COLDPLATES
11 FUEL CELL HEAT EXCHANGER
12 AVIONICS HEAT EXCHANGERS AND FANS
13 INERTIAL MEASUREMENT UNIT HEAT EXCHANGER AND FANS
14 WATER PUMPS
15 CONDENSER
16 WATER SEPARATORS
17 CABIN FANS LITHIUM HYDROXIDE
18 WATER CHILLER
19 LIQUID COOLING GARMENT HEAT EXCHANGER
20 FREON PUMPS





Briefly . . .

Silica glass tiles bonded to the Orbiter's skin have prompted some to call the spacecraft the "flying brickyard." The tiles on the outside and several types of insulation materials on the inside protect the Orbiter from temperature extremes while in orbit and from the searing heat of entering the atmosphere on the return trip. The lightweight glass tiles require only minor refurbishing between flights.

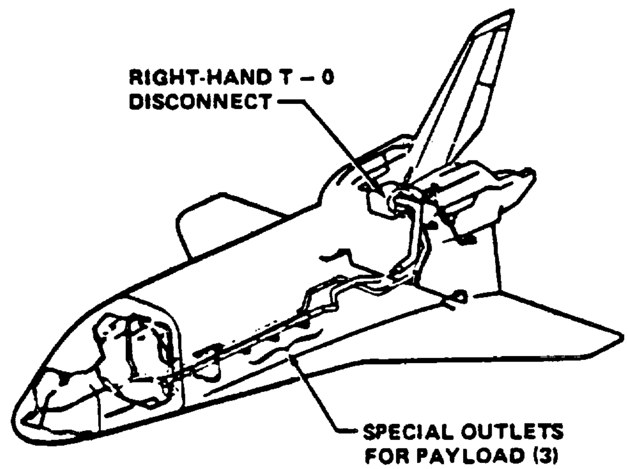
Insulation	Temperature limits	Area, m^2 (ft^2)	Weight, kg (lb)
Flexible reusable surface insulation	Below 644 K (371° C or 700° F)	319 (3 436)	499 (1 099)
Low-temperature reusable surface insulation	644 to 922 K (371° to 649° C or 700° to 1200° F)	268 (2 881)	917 (2 022)
High-temperature reusable surface insulation	922 to 978 K (649° to 704° C or 1200° to 1300° F)	477 (5 134)	3826 (8 434)
Reinforced carbon-carbon	Above 1533 K (1260° C or 2300° F)	38 (409)	1371 (3 023)
Miscellaneous			632 (1 394)
Total		1102 (11 860)	7245 (15 972)

Briefly . . .

The purge, vent, and drain system on the Orbiter removes gases and fluids that accumulate in the unpressurized spaces of the vehicle.

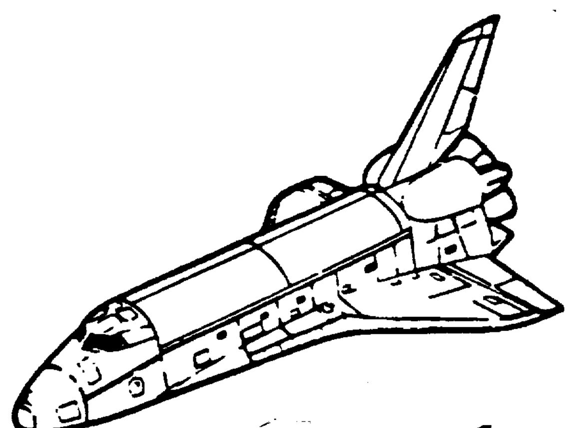
PURGE SUBSYSTEM (PREFLIGHT AND POSTFLIGHT)

Circulates conditioned gas during launch preparations to remove contaminants and toxic gases and maintain specified temperature and humidity



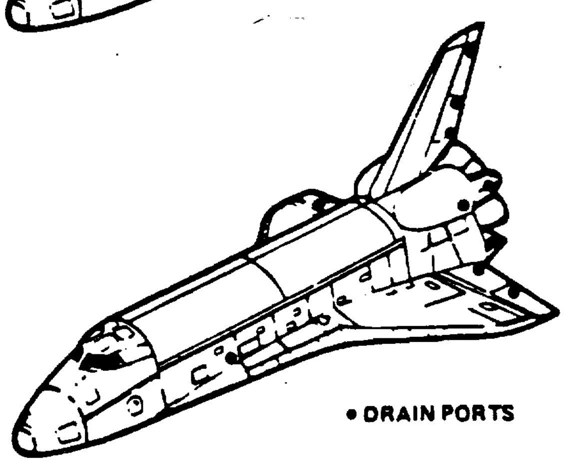
VENT SUBSYSTEM (ALL PHASES)

Allows unpressurized areas to depressurize during ascent and repressurize during descent and landing



DRAIN SUBSYSTEM (PREFLIGHT AND POSTFLIGHT)

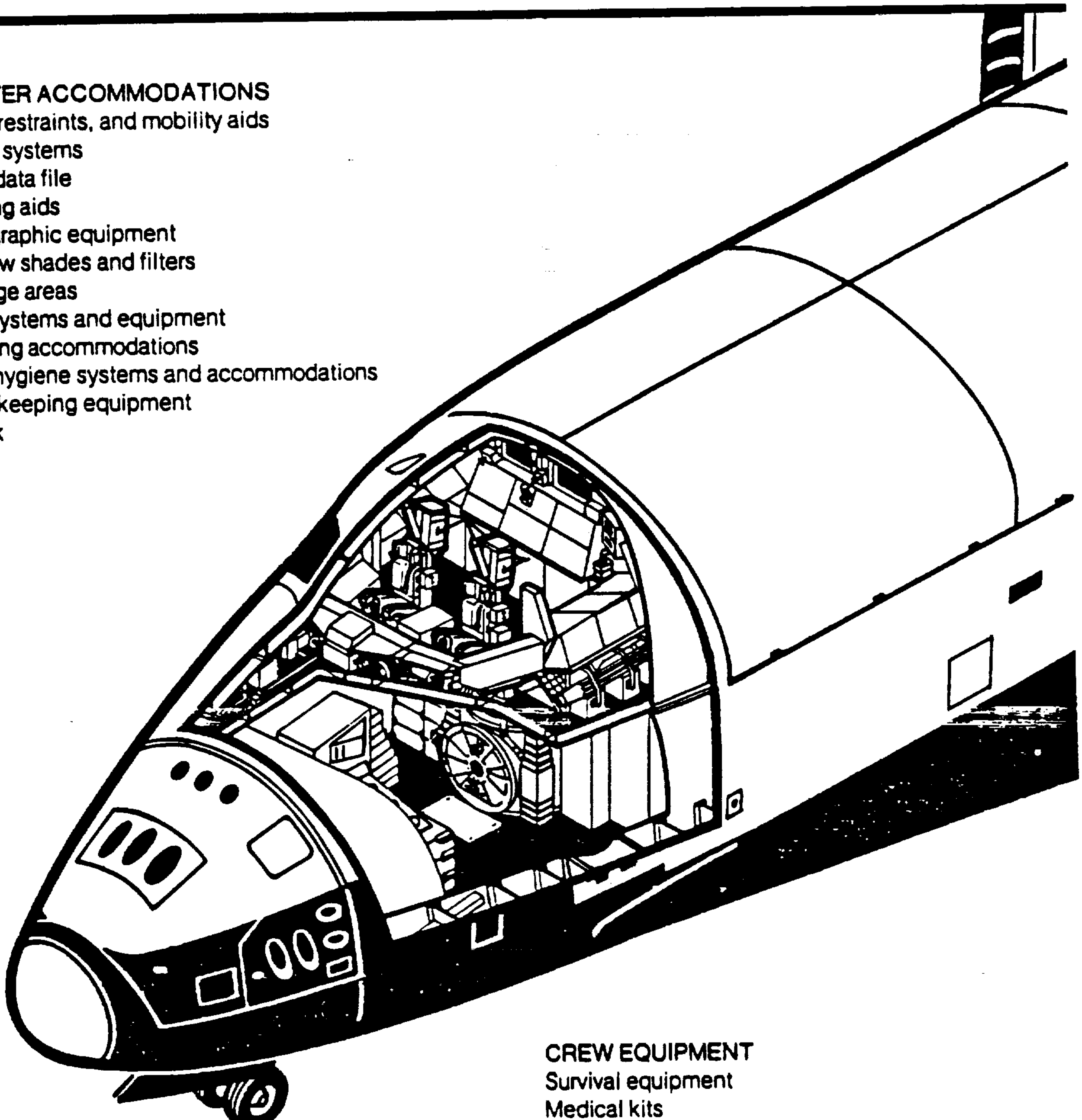
Removes accumulated water and other fluids



Briefly . . .

The Orbiter's crew quarters are outfitted with everything from a galley for preparing balanced meals and bunks for sleeping to all the equipment needed for keeping house in space. The only time space suits will be worn is during space walks. The Orbiter has a medicine chest and equipment for emergency rescue or survival.

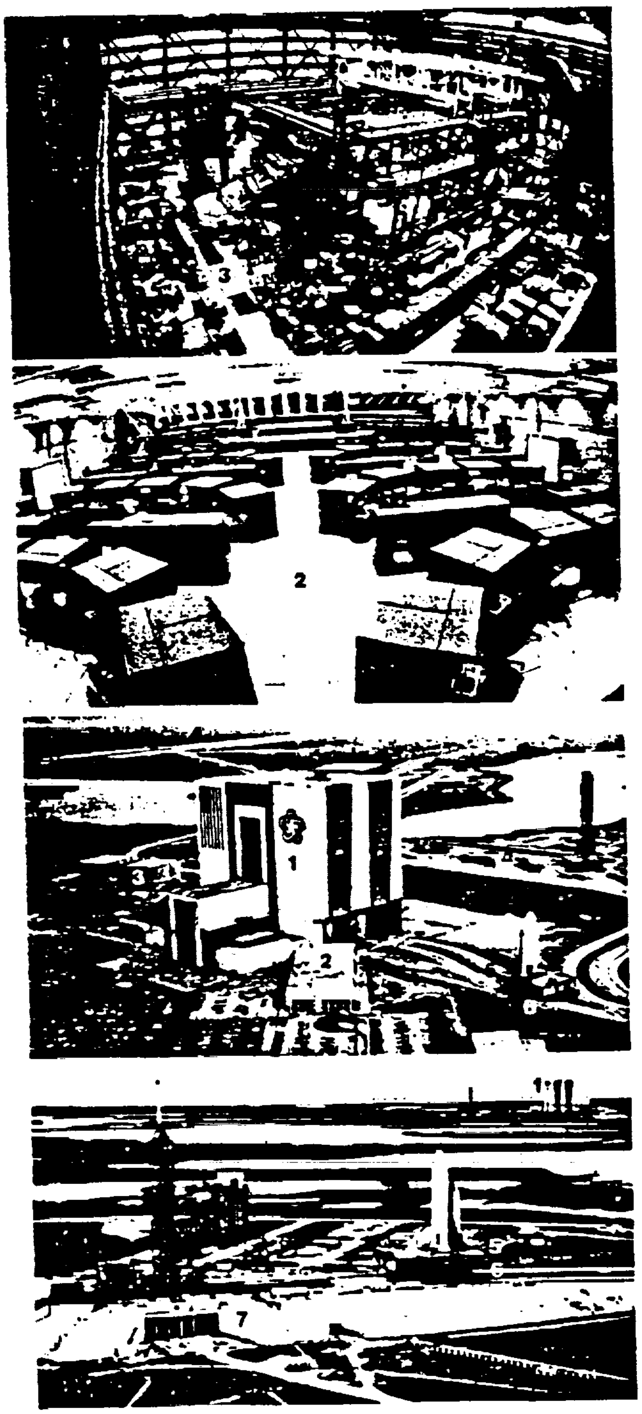
ORBITER ACCOMMODATIONS
Seats, restraints, and mobility aids
Egress systems
Flight data file
Sighting aids
Photographic equipment
Window shades and filters
Stowage areas
Food systems and equipment
Sleeping accommodations
Crew hygiene systems and accommodations
Housekeeping equipment
Airlock



CREW EQUIPMENT
Survival equipment
Medical kits
Radiation instrumentation
Operational bioinstrumentation
Crew clothing
Space suit assembly

Briefly . . .

The Space Shuttle Orbiter will be launched from and landed at either the Kennedy Space Center on the east coast or the Vandenberg Air Force Base on the west coast. Two Orbiters can be processed simultaneously at the new facility at KSC. The final countdown for a Shuttle launch at KSC will require only 2.5 hours, a significant drop from the 28 hours required for Apollo launches. The Orbiters are guided automatically to safe landings on a runway that is roughly twice as long and twice as wide as average commercial landing strips; the speed at touchdown is about 346 km/hr (215 mph).



1 VEHICLE ASSEMBLY BUILDING
3.3-hectare (8-acre) ground area
160 meters (525 feet) tall
218 meters (716 feet) long
158 meters (518 feet) wide
3 665 000-cubic-meter
(129 428 000-cubic-foot) volume

2 LAUNCH CONTROL CENTER
24 meters (77 feet) tall (4 stories)
115 meters (378 feet) long
55 meters (181 feet) wide

3 ORBITER PROCESSING FACILITY
29 meters (95 feet) tall
121 meters (397 feet) long
71 meters (233 feet) wide

4 SHUTTLE LANDING FACILITY
4572 meters (15 000 feet) long with
305-meter (1000-foot) safety
overruns at each end
91 meters (300 feet) wide

5 MOBILE LAUNCHER PLATFORM
7.6 meters (25 feet) tall
49 meters (160 feet) long
41 meters (135 feet) wide
Weight of platform: 3 733 000 kilograms (8 230 000 pounds)
Weight with Shuttle dry: 4 989 500 kilograms
(11 000 000 pounds)
Weight with Shuttle wet: 5 761 000 kilograms
(12 700 000 pounds)

6 CRAWLER-TRANSPORTER
6 meters (20 feet) tall
39.9 meters (131 feet) long
34.7 meters (114 feet) wide
2 721 000 kilograms (6 million pounds)
Speed:
Unloaded 3.2 km/hr (2 mph)
Loaded 1.6 km/hr (1 mph)

7 LAUNCH PAD AREA
67 hectares (165 acres)

Fixed Service Structure

The fixed service structure, located on the west side of the pad, is a square cross-section steel structure that provides access to the Shuttle Orbiter and to the rotating service structure. The FSS is essentially an open-framework structure 12.2 meters (40 feet) square and is permanently fixed to the pad surface. It incorporates several sections of the Saturn V umbilical towers removed from the Apollo mobile launchers in their conversion to Mobile Launcher Platforms. The FSS tower supports the hinge about which the rotary bridge supporting the RSS pivots as it moves between the Orbiter checkout position and the retracted position. A hammerhead crane situated atop the FSS provides hoisting services as required in pad operations. FSS work levels are at 6.1-meter (20-foot) intervals beginning at 8.2 meters (27 feet) above the surface of the pad. The height of the FSS from the pad surface to the top of the tower is 75.3 meters (247 feet). The height to the top of the hammerhead crane is 80.8 meters (265 feet), and the top of the lightning mast is 105.8 meters (347 feet) above the pad surface.

The FSS has three service arms: an access arm and two vent arms.

The Orbiter access arm (OAA) swings out to the Orbiter crew compartment hatch to provide personnel access to the forward compartments of the Orbiter. The outer end of the access arm ends in an environmental chamber that mates with the Orbiter and will hold six persons. The arm remains in the extended position until 2 minutes before launch to provide emergency egress for the crew. The Orbiter access arm is extended and retracted by two rotating actuators that rotate it through an arc of 70° in approximately 30 seconds. In its retracted position, the arm is latched to the FSS. The OAA is located 44.8 meters (147 feet) above the pad. It is 19.8 meters (65 feet) long, 1.5 meters (5 feet) wide, and 2.4 meters (8 feet) high and weighs 23 600 kilograms (52 000 pounds).

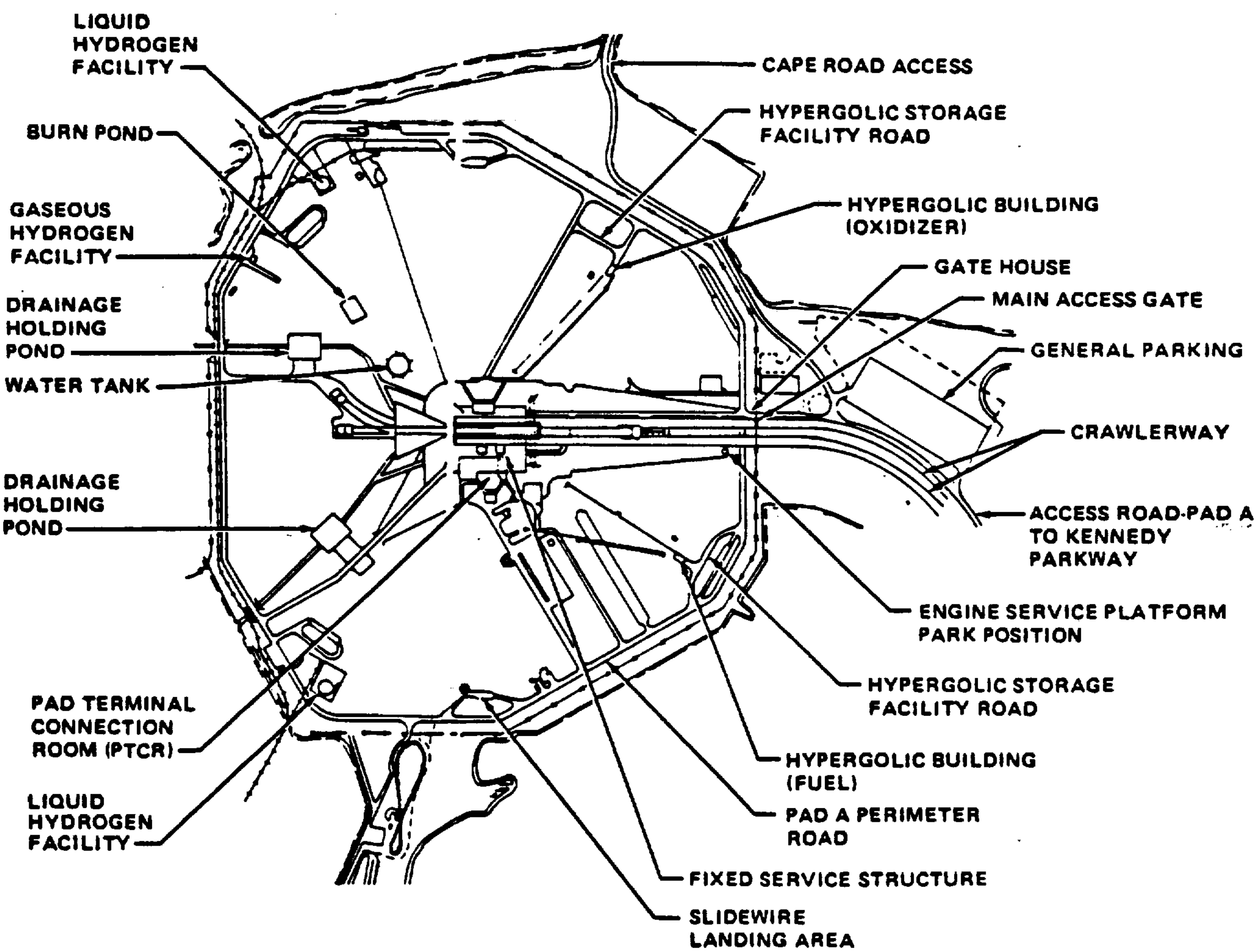


Figure 6-8.—Launch Pad 39-A surface arrangement.

The External Tank hydrogen vent line and access arm consists of a retractable access arm and a fixed supporting structure. This arm allows mating of the ET umbilicals and contingency access to the intertank interior while protecting sensitive components of the system from the launch environment.

The vent arm supports small helium and nitrogen lines and electrical cables, all mounted on a 20.3-centimeter (8-inch) inside-diameter hydrogen vent line. At SRB ignition, the umbilical is released from the Shuttle vehicle and retracted 84 centimeters (33 inches) into its latched position by a system of counterweights. The service lines rise approximately 46 centimeters (18 inches), pivot, and drop to a vertical position on the fixed structure where they are protected from the launch environment. All this activity occurs in approximately 4 seconds. The vent arm itself rotates through 210° of arc to its stowed position in about 3 minutes. The fixed structure is mounted on the northeast corner of the FSS 50.9 meters (167 feet) above the surface of the pad. The vent arm is 14.6 meters (48 feet) long and weighs 6800 kilograms (15 000 pounds).

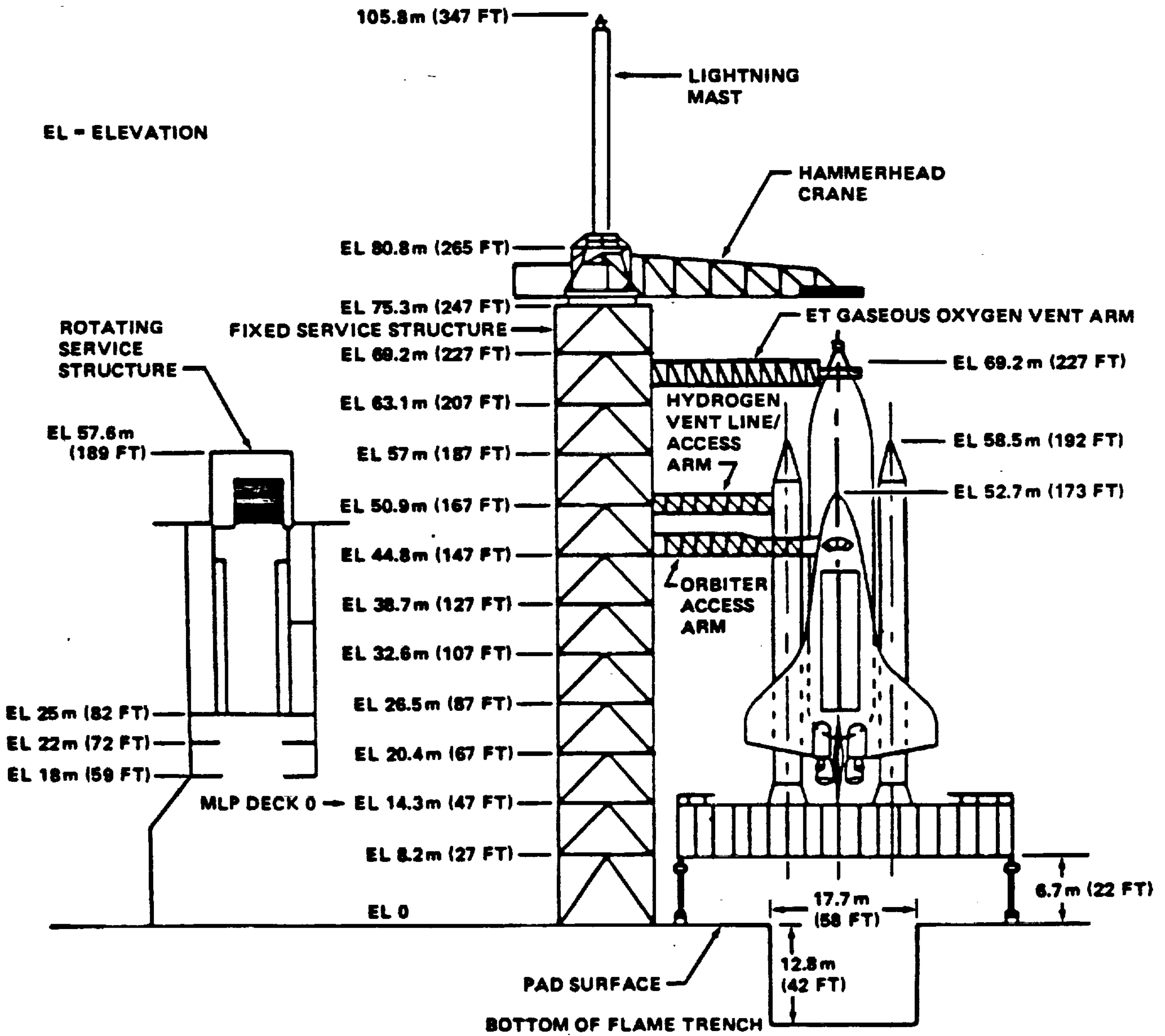
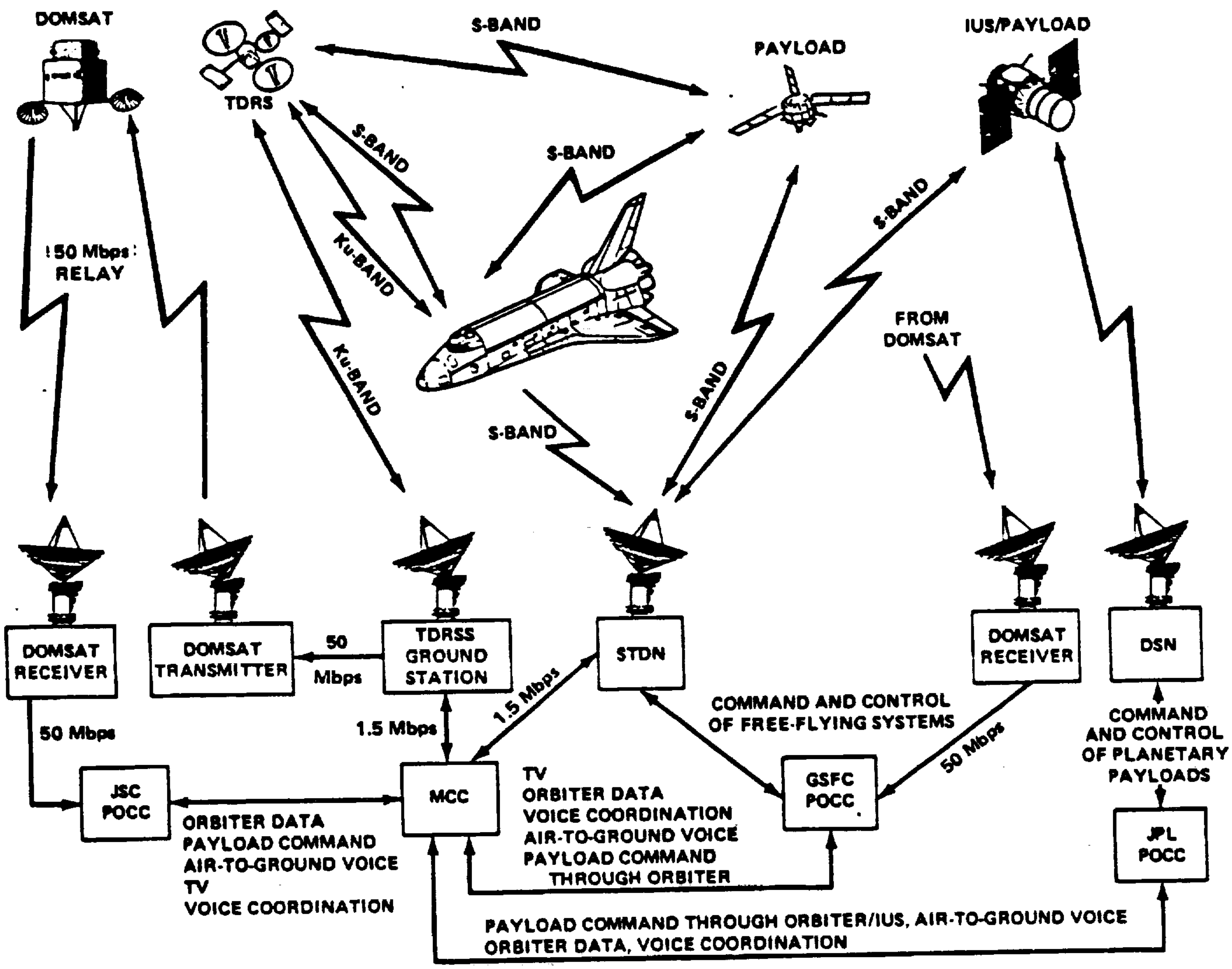


Figure 6-9.—Space Shuttle/pad elevations.

Briefly . . .

Tracking stations scattered around the world give Orbiter crews contact with Mission Control for several minutes of most orbits. When the new Tracking and Data Relay Satellites are parked at 37 000 kilometers (23 000 miles) over the Equator in the mid-1980's, the Mission Control Center will have almost continuous contact with Orbiter crews.



DOMSAT	DOMESTIC SATELLITE
DSN	DEEP SPACE NETWORK
GSFC	GODDARD SPACE FLIGHT CENTER
IUS	INERTIAL UPPER STAGE
JPL	JET PROPULSION LABORATORY
JSC	JOHNSON SPACE CENTER
MCC	MISSION CONTROL CENTER
POCC	PAYLOAD OPERATIONS CONTROL CENTER
STDN	SPACE TRACKING AND DATA NETWORK
TDRS	TRACKING AND DATA RELAY SATELLITE
TDRSS	TRACKING AND DATA RELAY SATELLITE SYSTEM

The network communications processing program monitors circuits; routes and formats data within the computer complex itself; and manages and controls the input of the computing system.

Data processing equipment.—The Shuttle Data Processing Complex has three IBM 370/168-1 computers. These mainframe computers are capable of processing 3 million instructions per second.

Display Control System

The Display Control System provides the link between the information being processed in the computer and the presentation of data on strip-chart recorders, scribing plotboards, event lights (similar to warning lights on automobiles), and the digital television system. The digital television system presents information in tabular form on television "pages" or channels. The system allows console operators to request data and specify the manner in which it is presented. Most of the data is available on the digital television system, which takes up most of the equipment in the control system.

MISSION CONTROL CENTER FLIGHT CONTROL FUNCTIONS AND POSITIONS

The Mission Control Center operations for the Space Shuttle are different from those of all previous programs in that operations planning and management is the main task and flight control, with the associated systems monitoring, is greatly decreased.

The Shuttle vehicle flight control and coordination with the Payload Operations Control Center (at the Goddard Space Flight Center, the Jet Propulsion Laboratory, and the Johnson Space Center) are performed from a flight control room. The flight control team, headed by a flight director, supports the vehicle and payload operations from the terminal countdown through launch, insertion, orbital operations, reentry, landing, and rollout.

The support provided by the multipurpose support teams (MPST's) is divided into two main categories: preflight planning and real-time support. The individual teams are dedicated to a specific discipline; therefore, their activity is a combination of planning and real-time support.

The maximum operations support required of the flight control and multipurpose support teams consists of up to three simultaneous operations, which can include combinations of real-time operations, a simulation, or pad support but no more than two actual flights.

Planning and Operations Management Team

The planning and operations management team (POMT) performs the vital function of managing the JSC preflight operations planning and is responsive to the JSC Shuttle Payload Integration and Development Program Office (SPIDPO) in performing this function. The management team is responsible for the detailed development, planning, scheduling, and statusing of all STS flights. The main POMT functions are as follows:

1. Communications and data management
2. Shuttle flight status management
3. Payload integration
4. Headquarters operations office representation
5. Medical management
6. Ground data systems management
7. Crew activities integration
8. Public affairs management
9. Training integration
10. Flight design and scheduling
11. Department of Defense representation
12. SPIDPO representation

Staffing for the POMT includes the following positions:

1. STS operations director
2. Communications/data manager
3. Shuttle flight status manager
4. Payload integrator
5. Headquarters representative
6. Ground data systems manager
7. Crew activity integrator
8. Public affairs officer
9. Training officer
10. Flight design and scheduling manager
11. Department of Defense representative
12. Medical representative
13. SPIDPO representative

Flight Control Team

Within the Mission Control Center, all real-time STS flight control responsibility is provided by the flight control team. Teammembers are assigned to a flight approximately 9 weeks before launch.

Launch/landing unique support.—The basic onorbit flight control team support is augmented with systems and trajectory experts for the launch, entry, and landing phases. For launch, entry, and landing phase support, the flight control team is composed of the following:

1. Flight director
2. Communications systems engineer (INCO)
3. Environmental/consumables mechanical engineer (EECOM)
4. Flight computer systems engineer
5. Avionics systems engineer
6. Propulsion systems engineer
7. Flight dynamics officer (FDO)
8. Trajectory officer (TRAJ)
9. Flight activities officer (FAO) (will also act as crew communicator if required)
10. Public affairs officer

Orbital support.—Following orbital stabilization of STS systems and trajectory conditions, the launch team support terminates and the orbit team continues support. The orbit team consists of the following:

1. Flight director
2. Communications systems engineer
3. Flight activities officer
4. Payload officer

Multipurpose Support Team

The multipurpose support teams support the planning and operations management team and the flight control teams concurrently. They are dedicated to specific functions. The multipurpose support rooms (MPSR's) contain communications and computer-driven display equipment that can be used by specialists in vehicle systems support (EECOM and guidance and propulsion), payload support systems, natural environment, communications and data management, crew activities, configuration/logistics, trajectory and flight design, flight scheduling, training support, ground data systems, medical support, and operations integration and requirements.

Staffing for the multipurpose support team includes the following positions:

1. Guidance and propulsion engineer
2. Avionics systems engineer
3. Main propulsion system engineer
4. Main engine controller engineer
5. Orbital maneuvering system/reaction control system engineer
6. Controls (flight control system) engineer
7. Sensors engineers
8. Data processing system engineer
9. Environmental, mechanical, and electrical system engineers
10. Payload support systems integrator
11. Natural (Earth) environment engineer
12. Crew activities integrator
13. Configuration/logistics engineer
14. Trajectory and flight design representative
15. Ground data systems manager
16. INCO engineer
17. Flight data manager
18. Assistant for flight data requests

The four EECOM positions (number 9) and their responsibilities are as follows.

1. EPS: Electrical power system (EPS) fuel cells and electrical power distribution system
2. APU/HYD: Auxiliary power unit/hydraulics (APU/HYD) systems, structural and mechanical systems, and landing systems
3. Thermal: Atmosphere revitalization system water loops, active thermal control subsystem, and structural temperatures
4. Life support: Waste management system; potable water system; purge, vent, and drain systems; food management; extravehicular activity and airlock; power reactant supply and distribution; atmospheric revitalization pressure control system; and ventilation systems

External Interfaces

Real-time interfaces for operations and planning are required with various organizations external to the Johnson Space Center throughout the STS operations phase.

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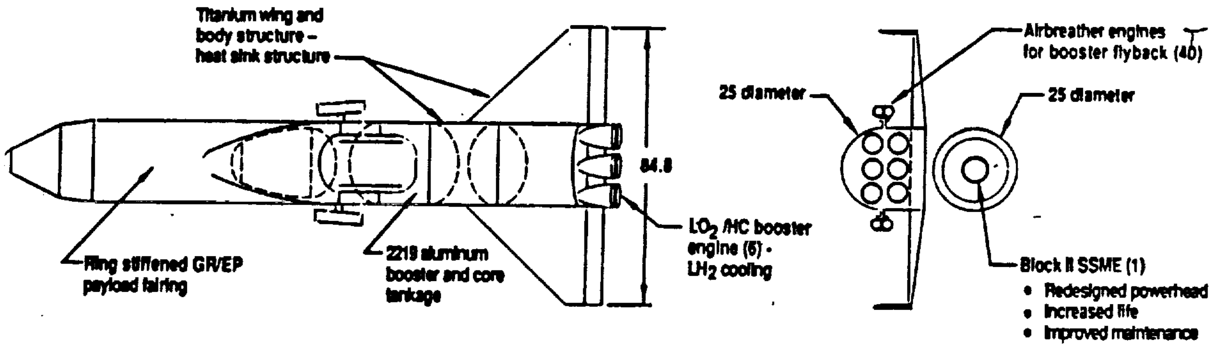
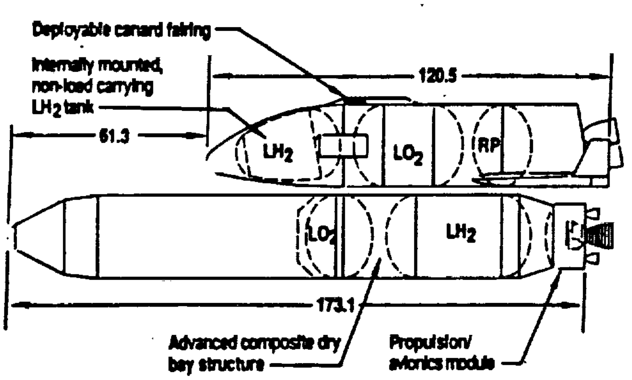
RFLY-PPA Configuration

Alternate Architecture

BOEING





Characteristic	RFLY booster	PPA Core
Gross lift-off weight Payload weight	2,127,511 80,900	
Total stage weight Usable propellant Inert weight Ideal velocity delta	1,416,203 1,197,033 219,170 11,985	616,902 552,932 63,970 19,042
Total ideal velocity	31,027	
Number of engines Type/propellants Rated thrust ISP Mixture ratio Chamber pressure Weight	6 Gas gen – LO_2/HC 445.6K/505.5K 358.6 3.35 4000 4375	2 Block II SSME–LO_2/LH_2 417.5K/512.3K 452.6 6 3000 7000

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RFLY-PPA CONFIGURATION - ALTERNATE ARCHITECTURE

The alternate RFLY-PPA configuration is slightly different in size and employs a different core stage engine than the recommended RFLY-PPA. With a gross lift-off weight of 2,127,511 lbs, this concept also places about 80,000 lbs into a 150 nautical mile circular orbit.

Except for the core stage engine, the configuration features for the RFLY and PPA are identical to those mentioned for the recommended system; refer there for more details.

The alternate PPA core stage propulsion system includes a block II version SSME, featuring a completely redesigned powerhead. this development is expected to increase the engine life and reduce required maintenance levels, while maintaining the performance characteristics of the standard Shuttle SSME.

6.6 APOLLO/SATURN

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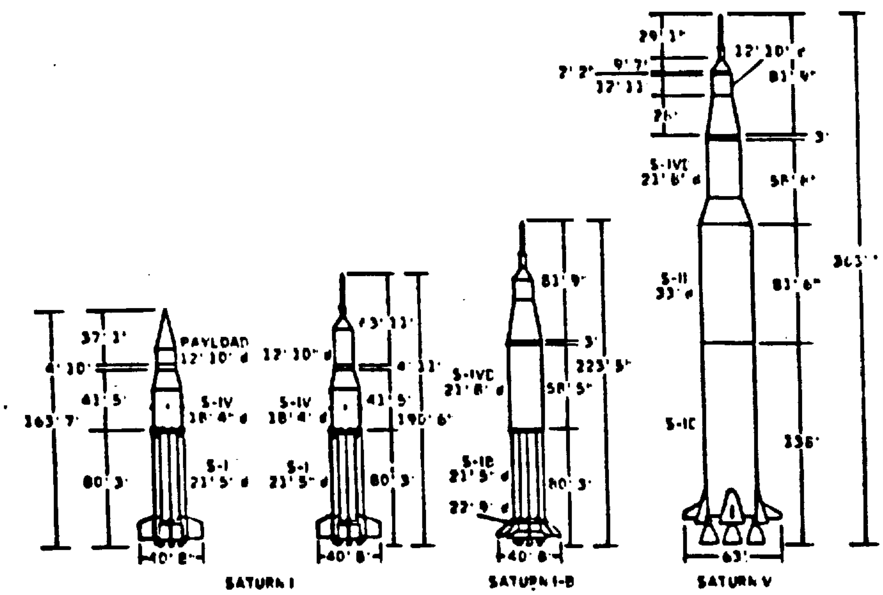

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6.6.1 APOLLO SPACECRAFT

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6.6.1 APOLLO SPACECRAFT

APOLLO SPACECRAFT

Overall Length .... 81 ft 9 inches (LEM adapter/IU interface to top of LES)

Weight Dry .... 32,000 lb

At Ground Ignition .... 96,500 lb

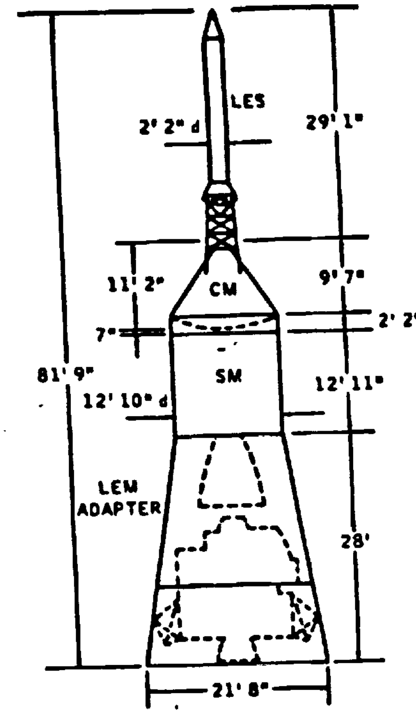
LEM (Fully Extended)
- Height .... 19 ft 4 inches
- Base Dimension .... 27 ft 4 inches (center of legs)
- Weight (At Ground Ingnition) ... 26,500 lb

LEM Adapter
- Length .... 28 ft
- Diameter .... Tapers from 21 ft 8 inches at bottom to 12 ft 10 inches at top
- Weight (At Ground Ignition) .... 3500 lb

SM
- Length (Including Fairing) ..... 15 ft 1 inch
- Diameter .... 12 ft 10 inches
- Weight (At Ground Ignition) ..... 50,500 lb

CM
- Length .... 11 ft 2 inches
- Diameter (Fairing Interface) ..... 12 ft 10 inches
- Weight (At Ground Ignition) ..... 9500 lb

LES
- Length .... 29 ft 1 inch (above CM tip)
- Diameter (Rocket Case) .... 2 ft 2 inches
- Weight (At Ground Ignition) .... 6500 lb



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6.6.2 SATURN I

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6.6.2 SATURN I

SATURN I, BLOCK I

Designation.....................SA-1 thru SA-4

Overall Dimensions

Diameter (S-I Midsection).......21 ft 5 inches

Diameter (Thrust Structure).......22 ft 9 inches

Length
SA-1 thru SA-3.............163 ft
SA-4.....................165 ft

Weight at Liftoff
SA-1 and SA-2.............926,300 lb
SA-3.....................1,060,000 lb
SA-4.....................940,000 lb

Rated Thrust....................1.32 million lb

Payload.......................Jupiter nose cone and adapter

Stages

S-I.......................Live

S-IV.......................Dummy

S-V-D.....................Dummy

Primary Mission.................S-I propulsion, structure, and control flight test

Secondary Missions

SA-2 and SA-3...............Project High Water

SA-3.....................Centaur dynamic pressure study

SATURN I, BLOCK I

S-I Stage

Manufacturer.................MSFC

Overall Dimensions
Diameter (Midsection).........21 ft 5 inches
Diameter (Thrust Structure).....22 ft 9 inches
Length..................81 ft 7 inches

Engines....................8
Type....................Rocketdyne H-1
Nominal Thrust (Each).........165,000 lb (sea level)
Mixture Ratio (Wo/Wf).........2.26:1
Outboard Gimbal Pattern.......7° square
Cant Angles..................6° (outboard engines)
3° (inboard engines)

Propellant Weight
SA-1, 2, and 4...............600,000 lb (LOX/RP-1)
SA-3....................750,000 lb (LOX/RP-1)

Separation
SA-1 and SA-2...............None
SA-3 and SA-4...............4 retromotors, system test only, no separation

S-IV Stage

Manufacturer.................MSFC

Overall Dimensions
Diameter..................18 ft 4 inches
Length...................43 ft 11 inches

SATURN I, BLOCK I

S-V-D Stage

Manufacturer.................MSFC/GDA

Overall Dimensions
Diameter..................10 ft
Length...................16 ft 1 inch

Payload

Overall Dimensions
Diameter..................10 ft
Length...................21 ft

SATURN I, BLOCK II

Designation....................SA-5 thru SA-10

Overall Dimensions

Diameter (S-I Midsection).......21 ft 5 inches

Diameter (Thrust Structure).......22 ft 9 inches

Diameter (With Fins)...........40 ft 8 inches

Length
Without Spacecraft...........126 ft 7 inches
SA-5.....................163 ft 7 inches
SA-6 and SA-7.............190 ft 6 inches
SA-8 thru SA-10............188 ft

Weight

At Ground Ignition.............1.165 million lb (two stages, IU, payload, and LES)

Rated Thrust (S-I)..............1.5 million lb

Stages

S-I.......................Live

S-IV.......................Live

Primary Mission

SA-5.....................S-I and S-IV propulsion, structure, and control flight test with Jupiter nose cone payload

SA-6 thru SA-10.............S-I and S-IV propulsion, structure, and control flight test with boilerplate Apollo payload

SATURN I, BLOCK II

Secondary Missions

SA-5 thru SA-10 .... S-I from S-IV separation

SA-6 thru SA-10 .... Guided flights

SA-6 thru SA-10 .... Jettison LES at S-IV ignition + 10 seconds

SA-8, SA-9, and SA-10 .... Micrometeoroid capsule

SA-10 .... Spacecraft separation

S-I Stage

Prime Contractor .... Chrysler

Maximum Diameter
Without Fins .... 22 ft 9 inches (thrust structure)
With Fins .... 40 ft 8 inches

Length .... 80 ft 3 inches

Weight
Dry .... 103,000 lb
At Ground Ignition .... 1,016 million lb

Engines .... Rocketdyne H-1 (8)

Total Nominal Thrust .... 1.5 million lb (sea level)

Propellant Capacity .... 880,000 lb (LOX/RP-1)
LOX .... 67,500 gal
RP-1 .... 42,400 gal

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SATURN I, BLOCK II

Mixture Ratio (Wo/Wf) 2.26:1

Outboard Gimbal Pattern .... 8° square

Cant Angles
Outboard .... 6°
Inboard .... 3°

Separation (S-I/S-IV) .... 4 ullage motors - Thiokol TX-280

S-IV Stage

Prime Contractor .... Douglas

Length .... 41 ft 5 inches

Diameter .... 18 ft 4 inches

Weight
Dry .... 13,000 lb (excludes 2100 lb for the S-I/S-IV interstage)
At Ground Ignition .... 114,000 lb (less interstage)

Engines .... 6; Pratt and Whitney RL10A-3

Total Nominal Thrust .... 90,000 lb (vacuum)

Propellant Capacity .... 100,000 lb
LOX .... 8750 gal
LH_2 .... 28,540 gal

Mixture Ratio (Wo/Wf) 5:1

75

VEHICLE PARAMETERS

SATURN I, BLOCK II

Instrument Unit

Prime Contractor .... MSFC

Length .... 4 ft 11 inches

Diameter .... 12 ft 10 inches

Weight (At Ground Ignition) .... 2700 lb

6.6.3 SATURN I-B

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6.6.3 SATURN I-B

SATURN IB

Overall Dimensions

Diameter
- S-IB Midsection.............21 ft 5 inches
- Thrust Structure.............22 ft 9 inches
- With Fins.................40 ft 8 inches

Length
- Without Spacecraft ....141 ft 9 inches
- With Spacecraft ....223 ft 5 inches

Weight (At Ground Ignition).......1.294 million lb (two stages, IU, payload, and LES)

Rated Thrust (S-IB) ....1.5 million lb

Stages

S-IB ....Live

S-IVB......................Live

S-IB Stage

Prime Contractor ....Chrysler

Maximum Diameter
- Without Fins ....22 ft 9 inches (thrust structure)
- With Fins ....40 ft 8 inches

Length ....80 ft 3 inches

Weight
- Dry ....91,000 lb
- At Ground Ignition............1.003 million lb

Engines ....8; Rocketdyne H-1

Total Nominal Thrust ....1.5 million lb (sea level)

SATURN IB

Propellant Capacity.............880,000 lb (LOX/RP-1)
- LOX.....................67,500 gal
- RP-1....................42,400 gal

Mixture Ratio (Wo/Wf)..........2.26:1

S-IVB Stage

Prime Contractor..............Douglas

Length ....58 ft 5 inches

Diameter ....21 ft 8 inches

Weight
- Dry......................20,000 lb (excludes interstage)
- At Ground Ignition............243,000 lb

Engine ....1; Rocketdyne J-2

Total Nominal Thrust...........200,000 lb (vacuum)

Propellant Capacity............219,000 lb (LOX/LH_2)
- LOX.....................20,650 gal
- LH_2....................72,860 gal

Mixture Ratio (Wo/Wf). 5:1

Instrument Unit

Prime Contractor..............MSFC

Length ....3 ft

Diameter.....................21 ft 8 inches

Weight (At Ground Ignition).......2600 lb

SATURN V

Vehicle

Number of Stages 3

Length
- Without Apollo Spacecraft . . . . 281 ft 11 inches
- With Apollo Spacecraft . . . . . 363 ft 8 inches

Maximum Diameter
- Without Fins ....33 ft
- With Fins ....63 ft

Weight ....Three stages, IU, Apollo Spacecraft
- Dry ....500,000 lb
- At Ground Ignition ....6,102,000 lb

S-IC Stage

Prime Contractor............Boeing

Length ....138 ft

Diameter
- Without Fins ....33 ft
- With Fins ....63 ft

Weight
- Dry ....287,000 lb
- At Ground Ignition.........4.7 million lb

Engines ....5; Rocketdyne F-1

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6.6.4 SATURN V

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6.6.4 SATURN V

SATURN V

S-IC Stage

Total Nominal Thrust............7.5 million lb (sea level)

Propellants..................LOX and RP-1

Propellant Capacity............4,400,000 lb
  LOX....................340,900 gal
  RP-1...................205,900 gal

Mixture Ratio (Wo/Wf)..........2.25:1

S-II Stage

Prime Contractor.............North American

Length....................81 ft 6 inches

Diameter...................33 ft

Weight
  Dry....................75,000 lb (excludes 13,800 lb for S-IC/S-II interstage and ullage motors)

  At Ground Ignition............1 million lb (excludes 13,800 lb for S-IC/S-II interstage and ullage motors)

Engines....................5; Rocketdyne J-2

Total Nominal Thrust............1 million lb (vacuum)

Propellants..................LOX and LH_2

Propellant Capacity............930,000 lb
  LOX....................82,700 gal
  LH_2....................263,000 gal

Mixture Ratio (Wo/Wf)..........5:1

60

SATURN V

S-IVB Stage

Prime Contractor..............Douglas

Length.....................58 ft 8 inches

Diameter (Forward of Interstage)...21 ft 8 inches

Weight
  Dry....................21,900 lb (excludes 7400 lb for S-II/S-IVB interstage and retromotors)

  At Ground Ignition............262,000 lb (excludes 7400 lb for S-II/S-IVB interstage and retromotors)

Engine................ - Rocketdyne J-2

Total Nominal Thrust..........200,000 lb (vacuum)

Propellants.................LOX and LH_2

Propellant Capacity............230,000 lb
  LOX....................20,652 gal
  LH_2...................72,860 gal

Mixture Ratio (Wo/Wf)..........5:1

Instrument Unit

Prime Contractor.............MSFC

Length.....................3 ft

Diameter...................21 ft 8 inches

Weight (At Ground Ignition).......3500 lb

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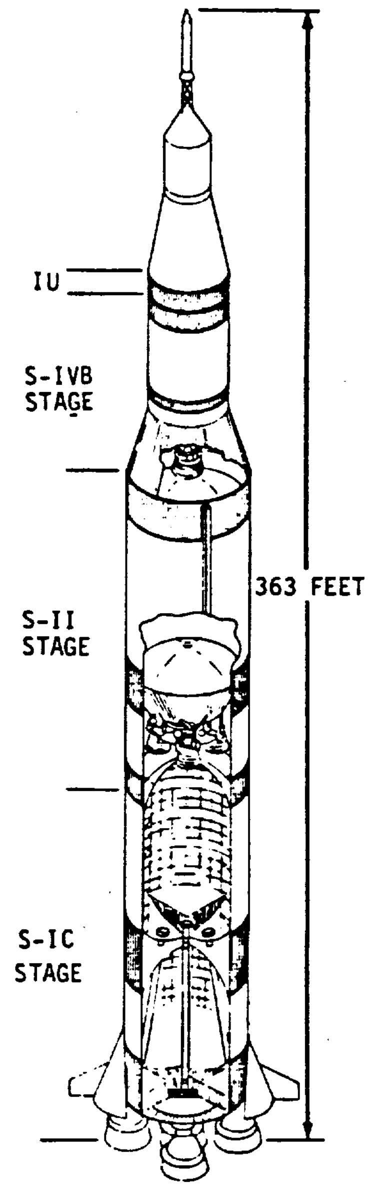
SATURN V LAUNCH VEHICLE

SOLID ULLAGE ROCKET AND RETROROCKET SUMMARY				
STAGE	TYPE	QUANTITY	NOMINAL THRUST AND DURATION	PROPELLANT GRAIN WEIGHT
S-IC	RETROROCKET	8	75,800 POUNDS • 0.541 SECONDS	278.0 POUNDS
S-II	ULLAGE	4	23,000 POUNDS † 3.75 SECONDS	336.0 POUNDS
	RETROROCKET	4	34,810 POUNDS ‡ 1.52 SECONDS	268.2 POUNDS
S-IVB	ULLAGE	2	3,390 POUNDS ** 3.87 SECONDS	58.8 POUNDS

ENGINE DATA					
STAGE	QTY	ENGINE MODEL	NOMINAL THRUST EACH	NOMINAL THRUST TOTAL	BURN TIME (MINUTES)
S-IC	5	F-1	1,530,000	7,650,000††	2.7
S-II	5	J-2	230,000	1,150,000	6.5
S-IVB	1	J-2	200,000	200,000	1ST 2.4 2ND 5.9

	STAGE DIMENSIONS		STAGE WEIGHTS	
	DIAMETER	LENGTH	DRY	AT LAUNCH
S-IC Base (including fins)	63.0 FEET	138 FEET	287,500 POUNDS	4,951,936 POUNDS
S-IC Mid-stage	33.0 FEET			
S-II Stage	33.0 FEET	81.5 FEET	78,050 POUNDS	1,086,835 POUNDS
S-IVB Stage	21.7 FEET	59.3 FEET	24,964 POUNDS	268,188 POUNDS
Instrument Unit	21.7 FEET	3.0 FEET	4,492 POUNDS	4,492 POUNDS

SATURN V STAGE MANUFACTURERS	
STAGE	MANUFACTURER
S-IC	THE BOEING COMPANY
S-II	NORTH AMERICAN-ROCKWELL
S-IVB	McDONNELL - DOUGLAS CORP.
S-IU	INTERNATIONAL BUSINESS MACHINE CORP.



PRE-LAUNCH LAUNCH VEHICLE GROSS WEIGHT ≈ 6,423,754 POUNDS

• MINIMUM VACUUM THRUST AT 120°F
† AT 170,000 FT. AND 70°F
‡ NOMINAL VACUUM THRUST AT 60°F
** AT 175,000 FT AND 70°F
†† AT SEA LEVEL

NOTE: THRUST VALUES, WEIGHTS, AND BURN TIMES ARE ALL APPROXIMATIONS.

Figure 1-3

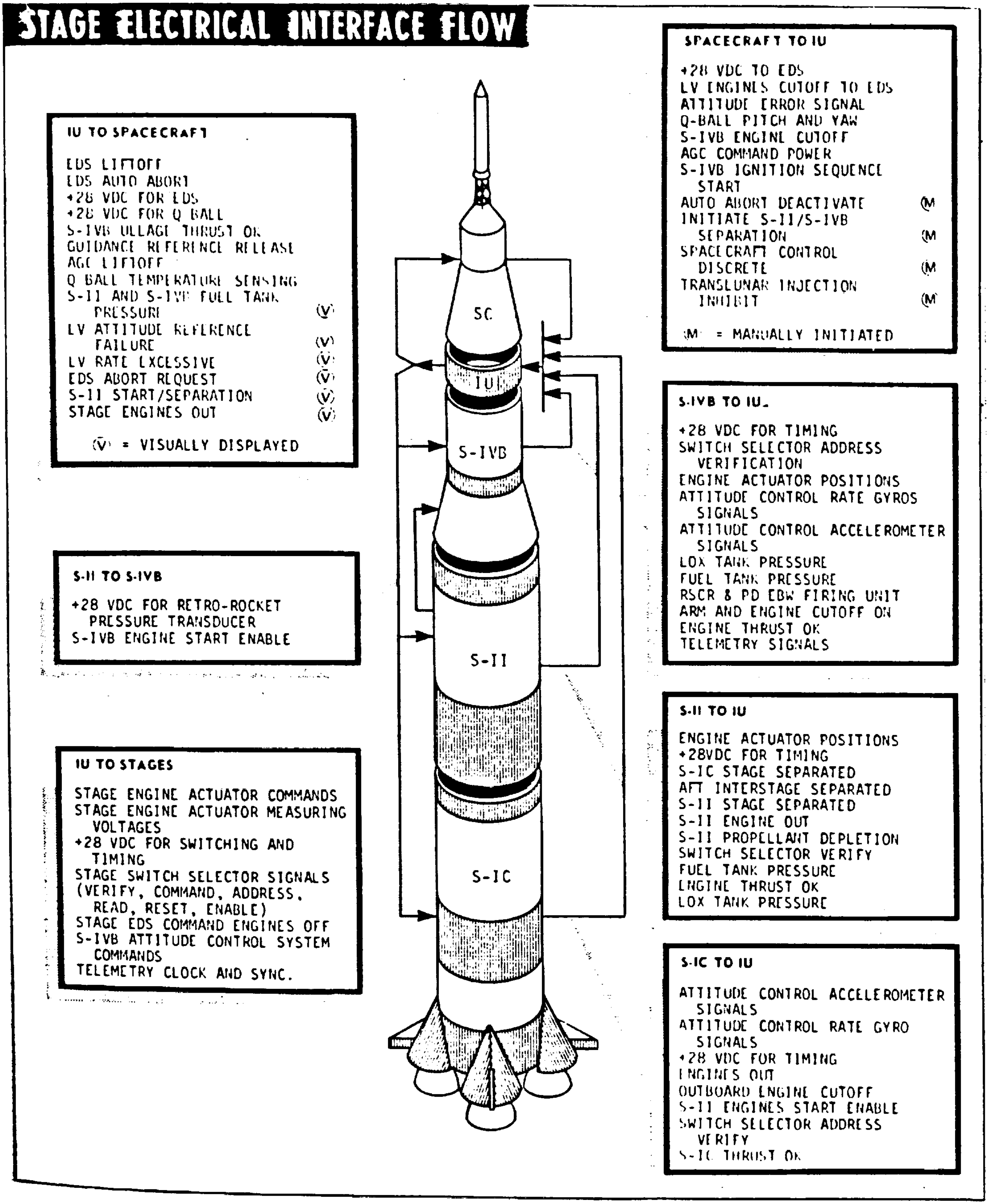

STAGE ELECTRICAL INTERFACE FLOW
IU TO SPACECRAFT
EDS LIFTOFF
EDS AUTO ABORT
+28 VDC FOR EDS
+28 VDC FOR Q BALL
S-IVB ULLAGE THRUST OK
GUIDANCE REFERENCE RELEASE
AGC LIFTOFF
Q BALL TEMPERATURE SENSING
S-II AND S-IVB FUEL TANK PRESSURE (V)
LV ATTITUDE REFERENCE FAILURE (V)
LV RATE EXCESSIVE (V)
EDS ABORT REQUEST (V)
S-II START/SEPARATION (V)
STAGE ENGINES OUT (V)
(V) = VISUALLY DISPLAYED
S-II TO S-IVB
+28 VDC FOR RETRO-ROCKET PRESSURE TRANSDUCER
S-IVB ENGINE START ENABLE
IU TO STAGES
STAGE ENGINE ACTUATOR COMMANDS
STAGE ENGINE ACTUATOR MEASURING VOLTAGES
+28 VDC FOR SWITCHING AND TIMING
STAGE SWITCH SELECTOR SIGNALS (VERIFY, COMMAND, ADDRESS, READ, RESET, ENABLE)
STAGE EDS COMMAND ENGINES OFF
S-IVB ATTITUDE CONTROL SYSTEM COMMANDS
TELEMETRY CLOCK AND SYNC.
SC
IU
S-IVB
S-II
S-IC
SPACECRAFT TO IU
+28 VDC TO EDS
LV ENGINES CUTOFF TO EDS
ATTITUDE ERROR SIGNAL
Q-BALL PITCH AND YAW
S-IVB ENGINE CUTOFF
AGC COMMAND POWER
S-IVB IGNITION SEQUENCE START
AUTO ABORT DEACTIVATE (M)
INITIATE S-II/S-IVB SEPARATION (M)
SPACECRAFT CONTROL DISCRETE (M)
TRANSLUNAR INJECTION INHIBIT (M)
(M) = MANUALLY INITIATED
S-IVB TO IU
+28 VDC FOR TIMING
SWITCH SELECTOR ADDRESS VERIFICATION
ENGINE ACTUATOR POSITIONS
ATTITUDE CONTROL RATE GYROS SIGNALS
ATTITUDE CONTROL ACCELEROMETER SIGNALS
LOX TANK PRESSURE
FUEL TANK PRESSURE
RSCR & PD EBW FIRING UNIT ARM AND ENGINE CUTOFF ON
ENGINE THRUST OK
TELEMETRY SIGNALS
S-II TO IU
ENGINE ACTUATOR POSITIONS
+28VDC FOR TIMING
S-IC STAGE SEPARATED
AFT INTERSTAGE SEPARATED
S-II STAGE SEPARATED
S-II ENGINE OUT
S-II PROPELLANT DEPLETION
SWITCH SELECTOR VERIFY
FUEL TANK PRESSURE
ENGINE THRUST OK
LOX TANK PRESSURE
S-IC TO IU
ATTITUDE CONTROL ACCELEROMETER SIGNALS
ATTITUDE CONTROL RATE GYRO SIGNALS
+28 VDC FOR TIMING
ENGINES OUT
OUTBOARD ENGINE CUTOFF
S-II ENGINES START ENABLE
SWITCH SELECTOR ADDRESS VERIFY
S-IC THRUST OK

Figure 1-4

TYPICAL CRITICAL EVENT SEQUENCE, FIRST OPPORTUNITY TLI (EVENT TIMES ARE BASED ON AS-509 LAUNCH VEHICLE OPERATIONAL TRAJECTORY FOR JANUARY 31, 1971 WINDOW, 72.067° FLIGHT AZIMUTH)		
TIME FROM FIRST MOTION (HR:MIN:SEC)	TIME FROM REFERENCE (HR:MIN:SEC)	EVENT
-0:00:17.3	T_1-0:00:17.7	Guidance Reference Release
0:00:00.0	T_1-0:00:00.4	First Motion
0:00:00.4	T_1+0:00:00.0	Liftoff
0:00:01.4	T_1+0:00:01.0	Begin Tower Clearance Yaw Maneuver
0:00:09.4	T_1+0:00:09.0	End Yaw Maneuver
0:00:12.3	T_1+0:00:11.9	Pitch and Roll Initiation
0:01:09.0	T_1+0:01:08.6	Mach 1
0:01:25.5	T_1+0:01:25.1	Maximum Dynamic Pressure
0:02:15.0	T_1+0:02:14.6	S-IC Center Engine Cutoff
0:02:15.1	T_2+0:00:00.0	Set Time Base 2
0:02:42.8	T_2+0:02:27.7	Begin Tilt Arrest
0:02:44.8	T_3+0:00:00.0	S-IC Outboard Engine Cutoff
0:02:45.3	T_3+0:00:00.5	S-II Ullage Rocket Ignition
0:02:45.5	T_3+0:00:00.7	Signal to Separation Devices and S-IC Retrorockets
0:02:45.6	T_3+0:00:00.8	S-IC/S-II First Plane Separation Complete
0:02:46.2	T_3+0:00:01.4	S-II Engine Start Sequence Initiated
0:02:47.2	T_3+0:00:02.4	S-II Ignition (Start Tank Discharge Valve Opens)
0:02:49.2	T_3+0:00:04.4	S-II Engines at Mainstage
0:02:49.8	T_3+0:00:05.0	S-II Ullage Thrust Cutoff
0:03:15.5	T_3+0:00:30.7	S-II Aft Interstage Drop (Second Plane Separation)
0:03:21.2	T_3+0:00:36.4	LET Jettison (Crew Action)
0:03:25.6	T_3+0:00:40.8	Initiate IGM
0:07:43.8	T_3+0:04:59.0	S-II Center Engine Cutoff
0:07:52.2	T_3+0:05:07.4	MR Shift
0:09:16.67	T_4-0:00:00.01	S-II Outboard Engine Cutoff; Enable Chi Freeze
0:09:16.68	T_4+0:00:00:0	Set Time Base 4; Begin Chi Freeze
0:09:17.6	T_4+0:00:00.9	S-IVB Ullage Ignition
0:09:17.7	T_4+0:00:01.0	Signal to Separation Devices and S-II Retrorockets
0:09:17.8	T_4+0:00:01.1	S-II/S-IVB Separation
0:09:17.8	T_4+0:00:01.1	S-IVB Engine Start Sequence, First Burn
0:09:20.8	T_4+0:00:04.1	S-IVB Ignition (Start Tank Discharge Valve Opens)
0:09:23.3	T_4+0:00:06.6	S-IVB Engine at Mainstage
0:09:25.4	T_4+0:00:08.7	S-IVB Ullage Thrust End
0:09:26.1	T_4+0:00:09.4	End Chi Freeze
0:09:29.5	T_4+0:00:12.8	S-IVB Ullage Case Jettison
0:11:35.6	T_4+0:02:18.9	Begin Chi Freeze
0:11:43.4	T_5-0:00:00.2	S-IVB Cutoff, First Burn
0:11:43.6	T_5+0:00:00.0	Set Time Base 5
0:11:43.9	T_5+0:00:00.3	S-IVB APS Ullage Ignition
0:11:53.4	T_5+0:00:09.8	Parking Orbit Insertion
0:12:03.6	T_5+0:00:20.0	Initiate Maneuver to and Maintain Local Horizontal Alignment (CSM Forward, Heads Down)
0:12:03.7	T_5+0:00:20.1	Begin Orbital Guidance
0:12:42.6	T_5+0:00:59.0	LH_2 Continuous Vent Open
0:13:10.6	T_5+0:01:27.0	S-IVB APS Ullage Cutoff
0:13:24.1	T_5+0:01:40.5	Begin Orbital Navigation
2:21:00.1	T_6+0:00:00.0	Begin S-IVB Restart Preparations
2:21:42.1	T_6+0:00:42.0	O_2H_2 Burner (Helium Heater) On
2:21:42.3	T_6+0:00:42.2	LH_2 Continuous Vent Closed
2:29:16.4	T_6+0:08:16.3	S-IVB APS Ullage Ignition
2:29:16.9	T_6+0:08:16.8	Helium Heater Off
2:30:30.1	T_6+0:09:30.0	Initiate J-2 Fuel Lead
2:30:33.1	T_6+0:09:33.0	S-IVB APS Ullage Cutoff
2:30:38.1	T_6+0:09:38.0	S-IVB Reignition (Start Tank Discharge Valve Opens)
2:30:40.6	T_6+0:09:40.5	S-IVB Engine at Mainstage
2:33:55.6	T_6+0:11:55.5	MR Shift (First Opportunity Only)
2:36:33.8	T_7-0:00:00.2	S-IVB Engine Cutoff, Second Burn
2:36:34.0	T_7+0:00:00.0	Set Time Base 7
2:36:34.5	T_7+0:00:00.5	LH_2 Continuous Vent Open
2:36:34.7	T_7+0:00:00.7	Lox Nonpropulsive Vent Open
2:36:34.8	T_7+0:00:00.8	LH_2 Nonpropulsive Vent Open
2:36:37.6	T_7+0:00:03.6	Flight Control Coast Mode On
2:36:39.0	T_7+0:00:05.0	Enable SC Control of LV
2:36:43.8	T_7+0:00:09.8	Translunar Injection
2:39:04.7	T_7+0:02:30.7	Lox Nonpropulsive Vent Closed
2:39:04.9	T_7+0:02:30.9	LH_2 Continuous Vent Closed
2:39:04.9	T_7+0:02:30.9	Initiate Maneuver to and Maintain Local Horizontal Alignment (CSM Forward, Heads Down)
2:51:34.0	T_7+0:15:00.0	LH_2 Nonpropulsive Vent Closed
2:51:34.0	T_7+0:15:00.0	Initiate Maneuver to and Maintain TD&E Attitude
3:01:34.0	T_7+0:25:00.0	CSM Separation (Variable)
3:16:34.0	T_7+0:40:00.0	CSM/LM Docking (Variable)
3:36:34.4	T_7+1:00:00.4	LH_2 Nonpropulsive Vent Open
3:51:34.0	T_7+1:15:00.0	LH_2 Nonpropulsive Vent Closed
3:56:34.0	T_7+1:20:00.0	SC/LV Final Separation (Variable)
4:11:34.0	T_7+1:35:00.0 (T_8-0:08:00.0)	Initiate Maneuver to and Maintain S-IVB Evasive Attitude (Variable)
4:19:34.0	T_8+0:00:00.0	Set Time Base 8
4:19:35.2	T_8+0:00:01.2	S-IVB APS Ullage Ignition
4:20:55.2	T_8+0.01:21.2	S-IVB APS Ullage Cutoff
4:29:14.2	T_8+0:09:40.2	Initiate Maneuver to and Maintain Lox Dump Attitude
4:36:14.0	T_8+0:16:40.0	LH_2 Continuous Vent Open
4:40:54.0	T_8+0:21:20.0	Start Lox Dump
4:41:14.0	T_8+0:21:40.0	LH_2 Continuous Vent Closed
4:41:42.0	T_8+0:22:08.0	End Lox Dump
4:42:54.2	T_8+0:23:20.2	Lox Nonpropulsive Vent Open
4:42:59.0	T_8+0:23:25.0	LH_2 Nonpropulsive Vent Open
5:59:34.0*	T_8+1:40:00.0*	Initiate Maneuver to and Maintain S-IVB APS Impact Burn Attitude
6:29:34.0*	T_8+2:10:00.0*	S-IVB APS Ullage Ignition
6:33:35.0*	T_8+2:14:01.0*	S-IVB APS Ullage Cutoff

* Subject to update by DCS guidance commands to the LVDC after real-time assessment.

Figure 2-1

Changed 1 January 1971

HIGH DYNAMIC PRESSURE/WIND LOADS

The launch vehicle bending moments through the high q region are dependent on the shape of the wind profile and the orientation of the wind vector with respect to the trajectory plane. The envelope of inflight bending moments resulting from the 95 percentile directional winds for February-April (5.4-7.5 knots) is shown in figure 2-29. The critical wind direction and altitude of peak wind speed are used to obtain the maximum loads.

CENTER ENGINE CUTOFF LOADS

S-IC center engine cutoff (CECO) is programmed for 135 seconds after first motion. Figure 2-30 shows the axial load at CECO. The nominal longitudinal load factor at CECO is 3.51 g's.

OUTBOARD ENGINE CUTOFF LOADS

S-IC outboard engine cutoff (OBECO) occurs at approximately 162 seconds after first motion. Axial load at OBECO is shown in figure 2-31. The nominal longitudinal load factor at OBECO is 3.75 g's.

ENGINE OUT CONDITIONS

Engine-out conditions, if they should occur, will affect the vehicle loads. The time at which the malfunction occurs, which engine malfunctions, peak wind speed and azimuth orientation of the wind, are all independent variables which combine to produce load conditions. Each combination of engine-out time, peak wind velocity, wind azimuth, and altitude at which the maximum wind shear occurs, produces a unique trajectory. Vehicle responses such as dynamic pressure, altitude, Mach number, angle-of-attack, engine gimbal angles, yaw and attitude angle time histories vary with the prime conditions. Structure test programs indicate a positive structural margin exists for this malfunction flight condition.

S-IC STAGE PROPELLANT WEIGHT SUMMARY		
AS-509 NOMINAL FLIGHT	LOX (POUNDS)	RP-1 (POUNDS)
CONSUMED PROPELLANT	3,269,509	1,415,196
BUILDUP AND HOLDDOWN	66,073	18,619
MAINSTAGE	3,189,161	1,387,102
THRUST DECAY	5,310	3,361
TAILOFF	1,635	414
FUEL BIAS	NONE	5,700
PRESSURIZATION	7,330	NONE
RESIDUAL PROPELLANT	37,017	23,014
TANKS	2,160	9,898
SUCTION LINES	32,362	6,478
INTERCONNECT LINES	330	NONE
ENGINES	2,165	6,339
ENGINE CONTROL SYSTEMS	NONE	299
TOTAL	3,306,526	1,438,210

Figure 2-22

S-II STAGE PROPELLANT WEIGHT SUMMARY		
AS-509 NOMINAL FLIGHT	LOX (POUNDS)	LH2 (POUNDS)
USABLE PROPELLANT	833,951	157,694
MAINSTAGE	828,003	154,222
BIAS	NONE	1,681
THRUST BUILDUP	1,002	484
THRUST DECAY	287	115
PRESSURIZATION GAS	4,659	1,192
UNUSABLE PROPELLANT	3,441	2,100
TRAPPED:	3,343	2,005
ENGINE AND LINES	1,563	244
INITIAL ULLAGE MASS	265	110
TANK AND SUMP (LESS BIAS)	1,515	1,651
VENTED GAS	98	95
TOTAL	837,392	159,794

Figure 2-23

S-IVB STAGE PROPELLANT WEIGHT SUMMARY (BASED ON 5.0:1 MR FOR BOTH BURNS)		
AS-509 NOMINAL FLIGHT	LOX (POUNDS)	LH2 (POUNDS)
USABLE PROPELLANT (INCLUDES NOMINAL PROPELLANT CONSUMPTION, FLIGHT PERFORMANCE RESERVE, AND FLIGHT GEOMETRY RESERVE)	188,273	39,162
FUEL BIAS TO MINIMIZE RANDOM RESIDUALS	NONE	430
UNUSABLE PROPELLANT	1,564	3,908
ORBITAL AND FLIGHT BOILOFF	405	2,493
SUBSYSTEMS	13	385
ENGINE TRAPPED	108	10
LINES AND TANK UNAVAILABLE	366	726
*BUILDUP TRANSIENTS	553	248
*DECAY TRANSIENTS	119	46
*FOR FIRST AND SECOND BURNS		
TOTAL	189,837	43,500

Figure 2-24

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6.6.5 LC-39

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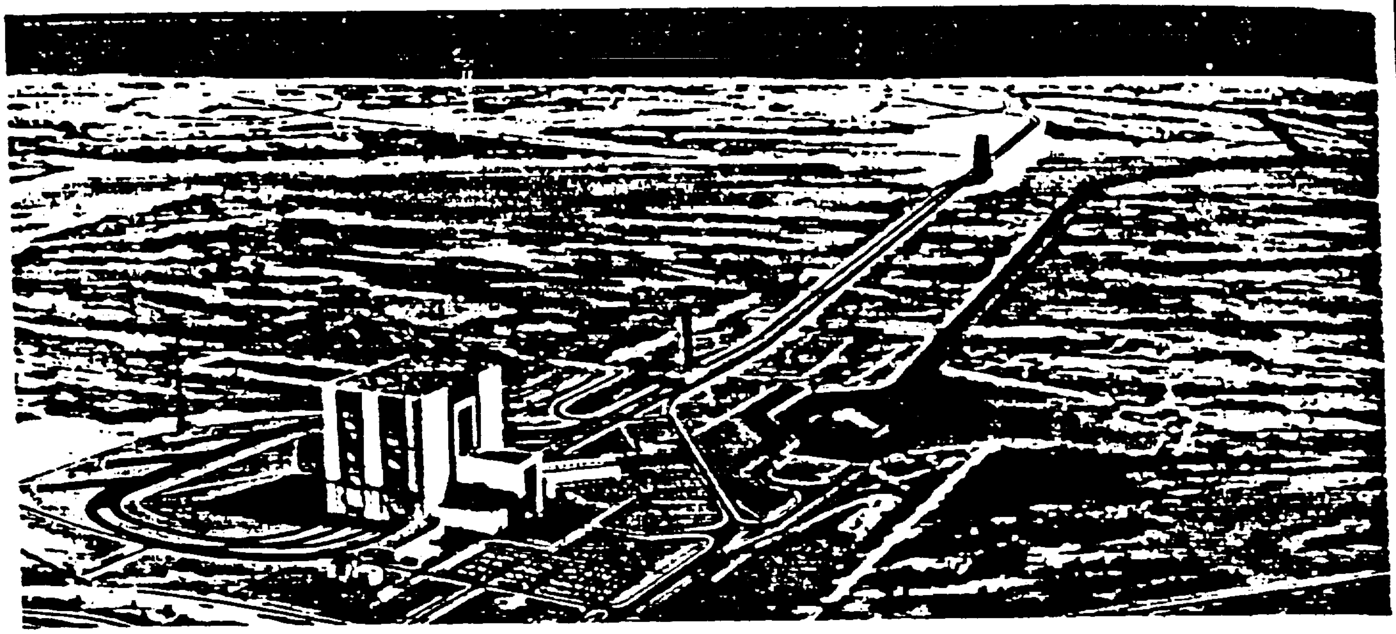
6.6.5 LC-39

LAUNCH COMPLEX 39



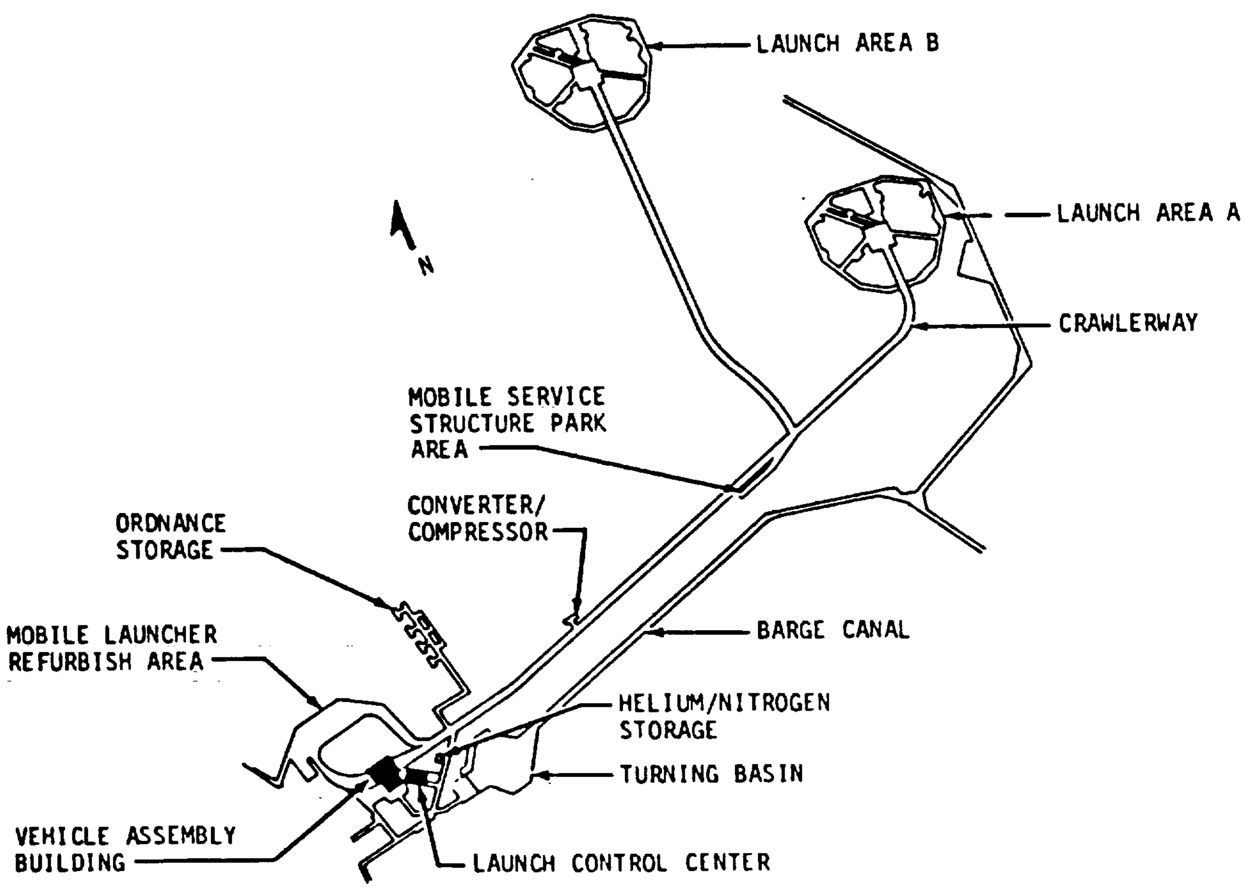


Figure 8-1

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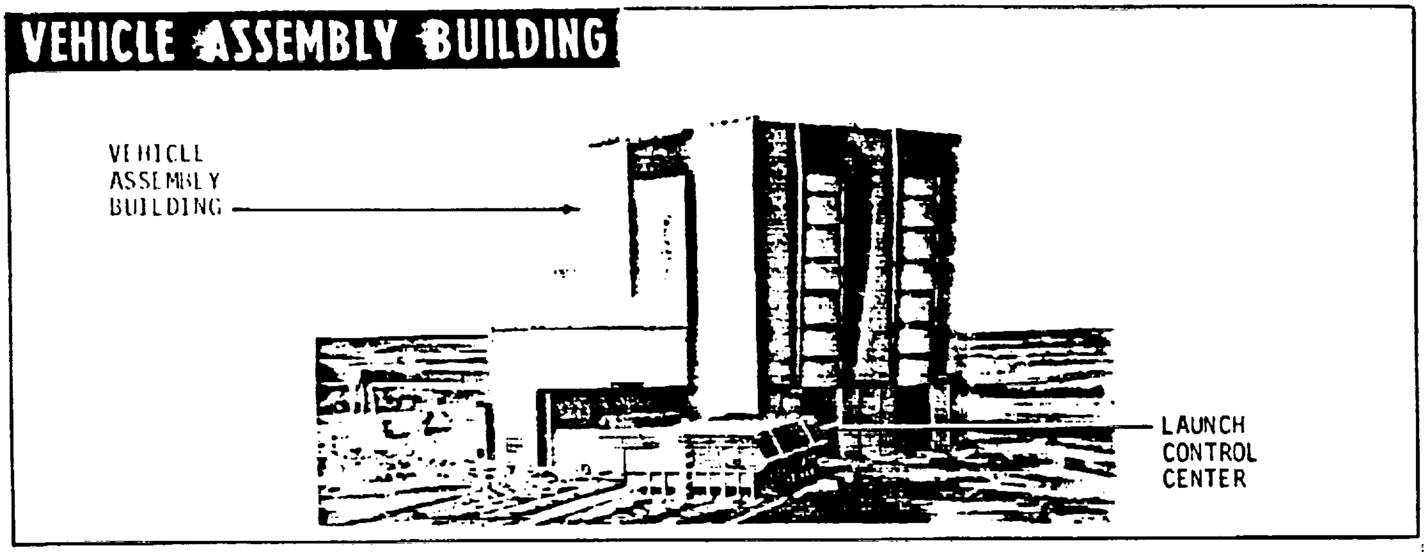

Figure 8-2

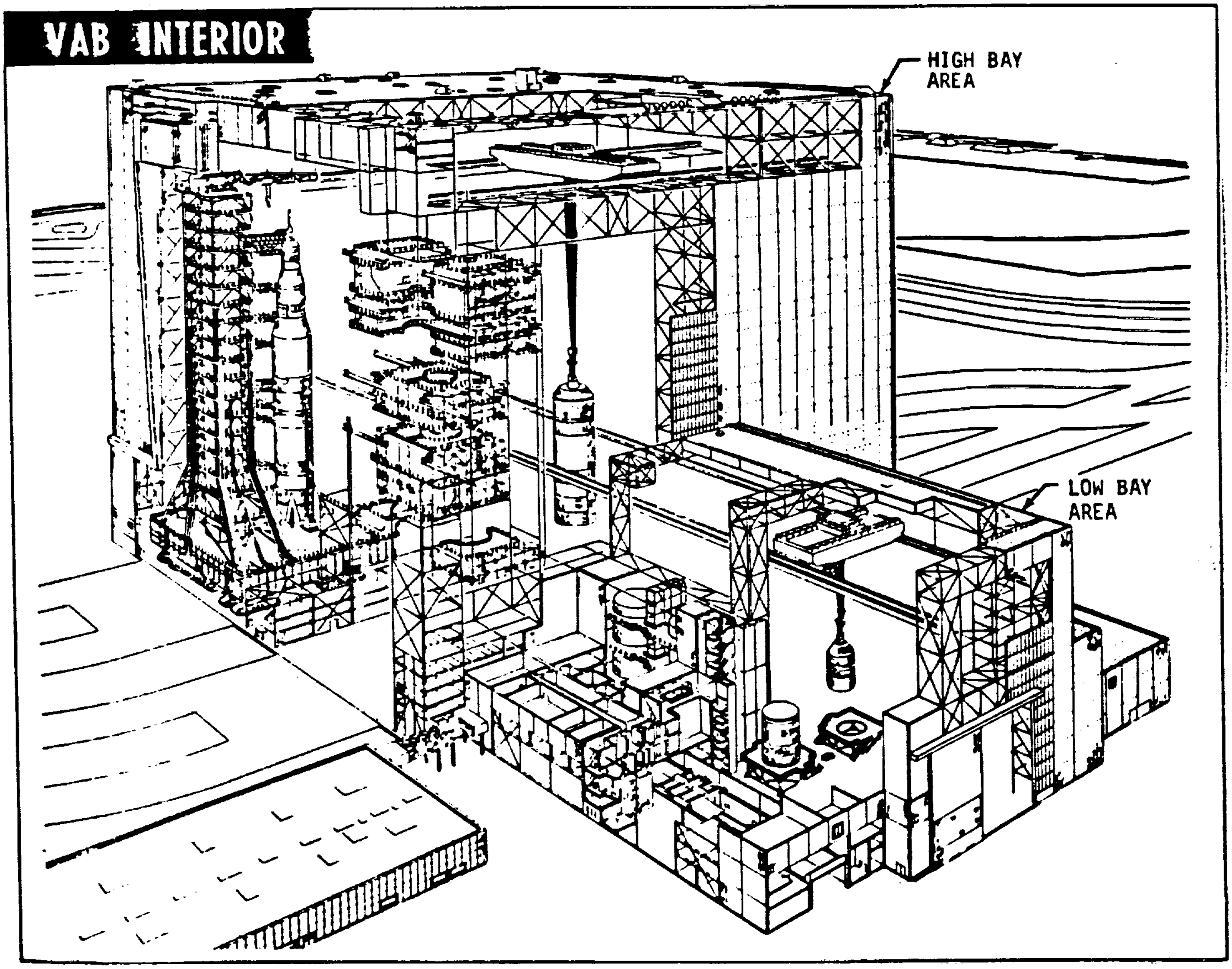

Figure 8-3

6.7 EXPENDABLE LAUNCH VEHICLES

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NASA Facts

National Aeronautics and
Space Administration

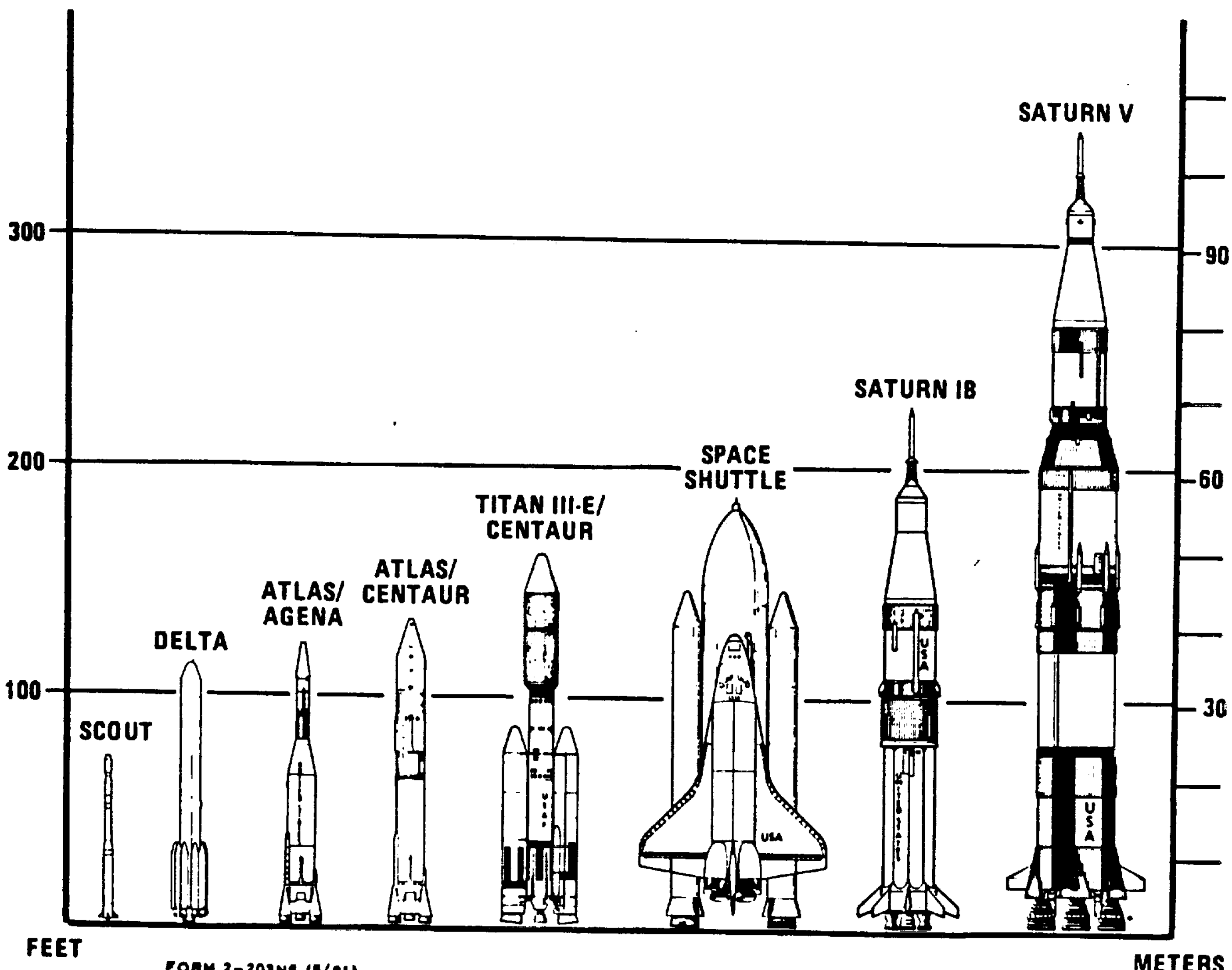
John F. Kennedy Space Center
Kennedy Space Center, Florida 32899
AC 305 867-2468

SPACE LAUNCH VEHICLES

KSC 135-81
Revised July 1986

Whatever space mission is undertaken, the vehicle carrying the payload must be propelled into space by rocket power. All unmanned rockets currently used by NASA have more than one stage and are usually referred to as launch vehicles. The manned Space Shuttle is a unique design, and in a class by itself.

The payload weight and the planned spacecraft destination determine what rocket capabilities are required for each mission. A low-weight spacecraft designed to operate in near-Earth orbit might be flown aboard NASA's smallest space vehicle, the Scout. Sending an Apollo manned spacecraft to the Moon required the massive Saturn V. The powerful Titan-Centaur combination sent large and complex unmanned scientific explorers like the Vikings and Voyagers to examine other planets. Atlas-Agenas sent several spacecraft to impact on the Moon. Atlas-Centaurs and Deltas have launched over 220 spacecraft, in a wide variety of applications that cover the broad range of the national space program. Of these, only the Scout, Delta, and Atlas-Centaur are still operational.



ATLAS/AGENA

The Atlas/Agena was a multi-purpose two-stage liquid propellant rocket. It was used to place unmanned spacecraft in Earth orbit, or inject them into the proper trajectories for planetary or deep-space probes.

The programs in which the versatile Atlas/Agena was utilized included early Mariner probes to Mars and Venus, Ranger photographic missions to the Moon, the Orbiting Astronomical Observatory (OAO), and early Applications Technology Satellites (ATS). The Agena upper stage also was used as the rendezvous target vehicle for the Gemini spacecraft during this series of two-man missions in 1965-1966. In preparation for the manned lunar landings, Atlas/Agena launched lunar orbiter spacecraft which went into orbit around the Moon and took photographs of possible landing sites.

The Atlas/Agena stood 36.6 meters (120 feet) high, and developed a total thrust at liftoff of approximately 1,725,824 newtons (388,000 pounds). It was last used in 1968 to launch an Orbiting Geophysical Observatory (OGO).

SATURN V

The Saturn V, America's most powerful staged rocket, carried out the ambitious task of sending astronauts to the Moon. The first Saturn V vehicle, Apollo 4, was launched on November 9, 1967. Apollo 8, the first manned flight of the Saturn V, was also the first manned flight to the Moon; launched in December 1968, it orbited the Moon but did not land. Apollo 11, launched on a Saturn V on July 16, 1969, achieved the first lunar landing.

Saturn V began its last manned mission on December 7, 1972, when it sent Apollo 17 on the final lunar exploration flight. It was last used on May 14, 1973, when it lifted the unmanned Skylab space station into Earth orbit, where it was occupied by three crews for a total of 171 days.

All three stages of the Saturn V used liquid oxygen as the oxidizer. The first stage burned kerosene with the oxygen, while the fuel for the two upper stages was liquid hydrogen. Saturn V, with the Apollo spacecraft and its small emergency escape rocket on top, stood 111 meters (363 feet) tall, and developed 34.5 million newtons (7.75 million pounds) of thrust at liftoff.

SATURN IB

The Saturn IB was originally used to launch Apollo lunar spacecraft into Earth orbit, to train for manned flights to the Moon. The first launch of a Saturn IB with an unmanned Apollo spacecraft took place in February 1966. A Saturn IB launched the first manned Apollo flight, Apollo 7, on October 11, 1968.

After the completion of the Apollo program, the Saturn IB launched three missions to man the Skylab space station in 1973. In 1975 it launched the American crew for the Apollo/Soyuz Test Project, the joint U.S./Soviet Union docking mission.

Saturn IB was 69 meters (223 feet) tall with the Apollo spacecraft and developed 7.1 million newtons (1.6 million pounds) of thrust at liftoff.

TITAN III-E/CENTAUR

The Titan III-E/Centaur, first launched in 1974, had an overall height of 48.8 meters (160 feet). Designed to use the best features of three proven rocket propulsion systems, this vehicle gave the U.S. an extremely powerful and versatile rocket for launching large spacecraft on planetary missions.

The Titan III-E/Centaur was the launch vehicle for two Viking spacecraft to Mars, and two Voyager spacecraft to Jupiter and Saturn. It also launched two Helios spacecraft toward the Sun. All provided remarkable new information about our solar system. The Vikings and Voyagers produced spectacular color photographs of the planets they explored.

The Titan III-E booster was a two-stage liquid-fueled rocket with two large solid-propellant rockets attached. At liftoff, the solid rockets provided 10.7 million newtons (2.4 million pounds) of thrust.

The Centaur stage, still in use today, produces 133,440 newtons (30,000 pounds) of thrust from two main engines, and burns for up to seven and one-half minutes. The Centaur can be restarted several times, which allows for more flexibility in launch times.

CURRENT LAUNCH VEHICLES

NASA has four active launch vehicles, the Space Shuttle, Atlas-Centaur, Delta, and Scout. The Kennedy Space Center launches Atlas-Centaurs and Deltas from pads on the Cape Canaveral Air Force Station, and Space Shuttles from pads on Kennedy. The NASA Langley Research Center launches Scouts from Vandenberg AFB in California and Wallops Flight Facility on the east peninsula coast of Virginia. Visiting teams from Italy sometimes launch Scouts from San Marco, a man-made platform in the ocean off the east coast of Africa.

Many of the launches conducted by NASA are for commercial organizations, other Federal agencies, other nations, or multi-national groups such as the International Telecommunications Satellite Organization. NASA is reimbursed for the cost of the rocket and launch services for such missions.

DELTA

Delta is called the workhorse of the space program. This vehicle has successfully transported over 160 scientific, weather, communications and applications satellites into space. These include the TIROS, Nimbus and ITOS weather observers; the Landsat Earth resources technology satellites; the early Intelsat international communications satellites; and many Explorer scientific spacecraft.

First launched in May, 1960, the Delta has been continuously upgraded over the years. Today it stands 35.4 meters (116 feet) tall. Its first stage is augmented by nine Caster IV strap-on solid propellant motors, six of which ignite at liftoff and three after the first six burn out 58 seconds into the flight. The average first-stage thrust with the main engines and six solid-propellant motors burning is 3,196,333 newtons (718,000 pounds). Delta has liquid-fueled first and second stages and a solid-propellant third stage. For most launches today, this third stage has been replaced by a Payload Assist Module (PAM) stage attached to the spacecraft.

The new PAM upper stage is also used on Space Shuttle launches. It boosts spacecraft from the low Earth orbit achieved by the Shuttle orbiter into higher ones. Many spacecraft, especially communications satellites, operate in a geosynchronous (geostationary) orbit some 35,792 kilometers (22,240 miles) above the equator. With the PAM and a recent change to a more powerful second stage, the Delta can lift some 1,270 kilograms (2,800 pounds) into a highly elliptical orbit, for transfer into geosynchronous orbit by a motor built into the spacecraft. This is almost double the 680 kilograms (1,500 pounds) a Delta could manage only seven years ago.

Delta vehicles were developed under the direction of NASA's Goddard Space Flight Center at Greenbelt, Maryland, and are built by the McDonnell Douglas Corporation.

ATLAS/CENTAUR

The Atlas/Centaur is NASA's standard launch vehicle for intermediate payloads. It is used for the launch of Earth orbital, geosynchronous, and interplanetary missions.

Centaur was the nation's first high-energy, liquid-hydrogen liquid-oxygen launch vehicle stage. It was developed under the direction of NASA's Lewis Research Center at Cleveland, Ohio, and became operational in 1966 with the launch of Surveyor 1, the first U.S. spacecraft to soft-land on the Moon.

Since 1966, both the Atlas booster and the Centaur second stage have undergone many improvements. At present, the combined stages can place over 4,530 kilograms (10,000 pounds) in low-Earth orbit, about 2,020 kilograms (4,453 pounds) in geosynchronous transfer orbit, and over 1,000 kilograms (2,205 pounds) on an interplanetary trajectory.

An Atlas-Centaur stands 41.9 meters (137.6 feet) tall. At liftoff, the Atlas booster develops over 1.9 million newtons (438,400 pounds) of thrust. The Centaur second stage develops 146,784 newtons (33,000 pounds) of thrust in a vacuum. General Dynamics/Convair is the prime contractor for Atlas/Centaur.

Spacecraft launched by Atlas/Centaurs include Orbiting Astronomical Observatories; Applications Technology Satellites; Intelsat IV, IV-A and V communications satellites; Mariner Mars orbiters; a Mariner spacecraft which made a fly-by of Venus and three of Mercury; Pioneer spacecraft which accomplished fly-bys of Jupiter and Saturn; and Pioneers that orbited Venus and plunged through its atmosphere to the surface.

SCOUT

The Scout launch vehicle, which became operational in 1960, has been undergoing systematic upgrading since 1976. The standard Scout vehicle is a solid-propellant, four-stage booster system approximately 23 meters (75 feet) in length with a launch weight of 21,600 kilograms (46,620 pounds) and liftoff thrust of 588,240 newtons (132,240 pounds).

Launch Failure History

BOEING

	First flight	Failure rate	Historical reliability
STS	1981	1/25	96.0%
Titan (overall) (T-34D)	1964 (1981)	6/136 (2/9)	95.6% (77.8%)
Delta	1960	12/179	93.3%
Atlas-Centaur	1962	6/60	90.0%
Ariane	1979	4/18	77.8%

1987

6.7.1 DELTA

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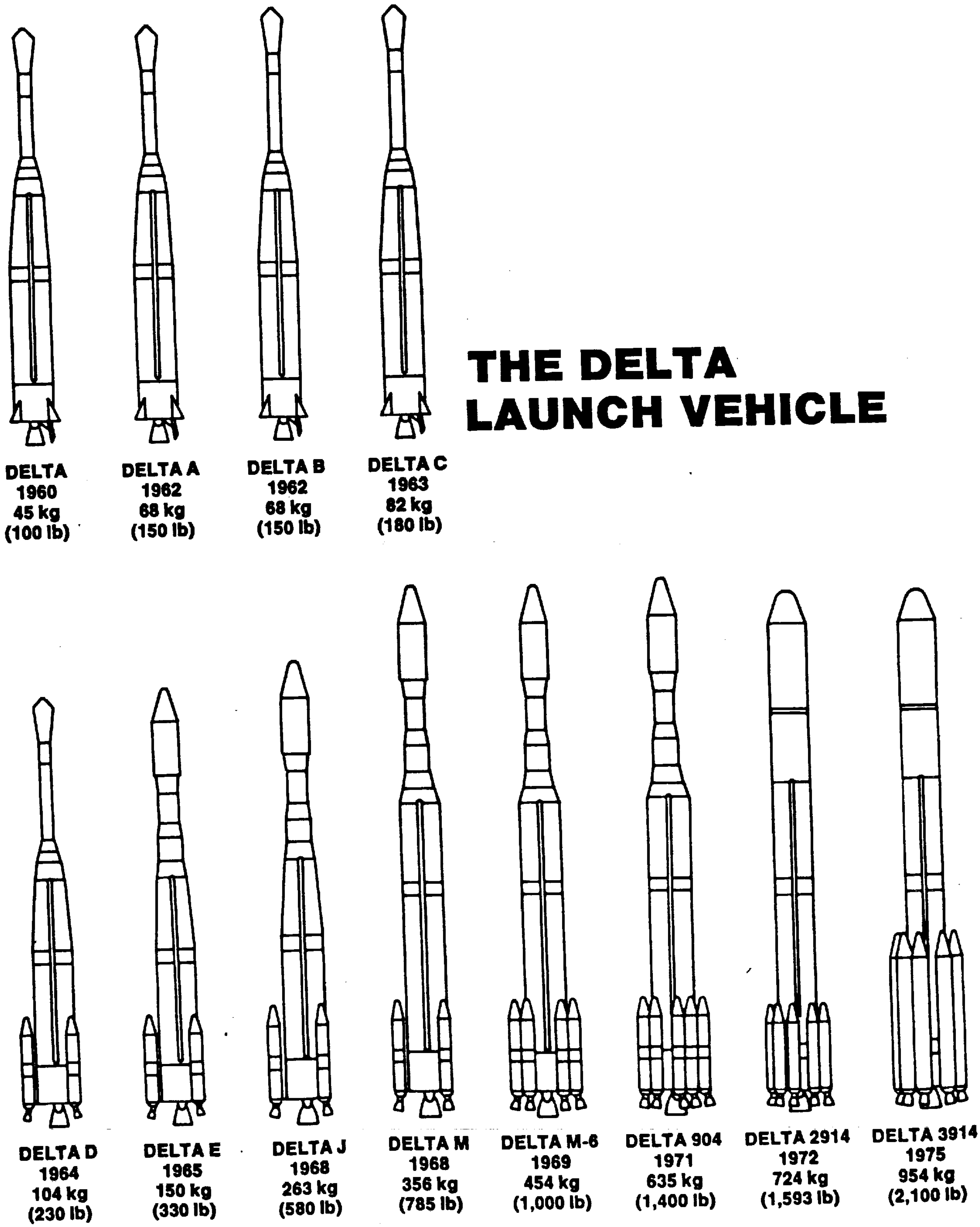
6.7.1 DELTA

THE DELTA LAUNCH VEHICLE



Over the years, the Delta Launch Vehicle has been improved in its performance and launch-to-orbit capabilities to meet the needs of the more sophisticated spacecraft systems destined for space. Since 1960, there have been 14 major configuration changes to the launch vehicle.

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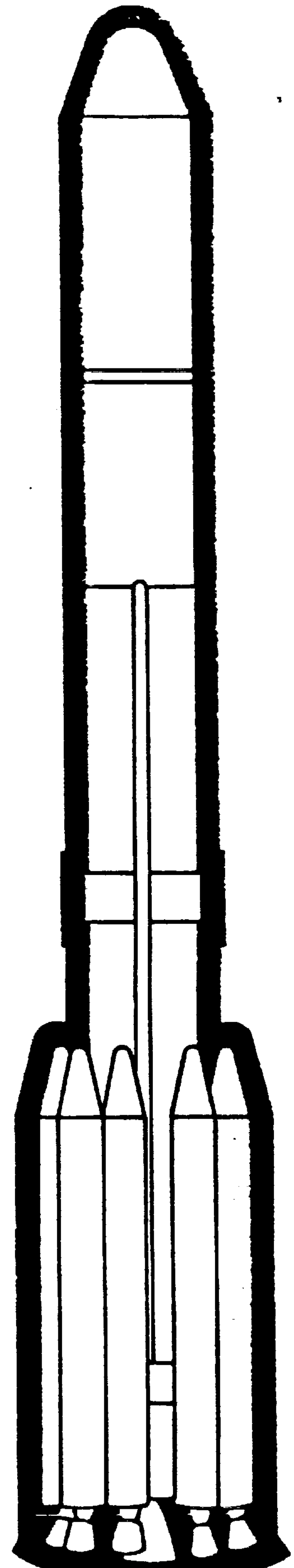
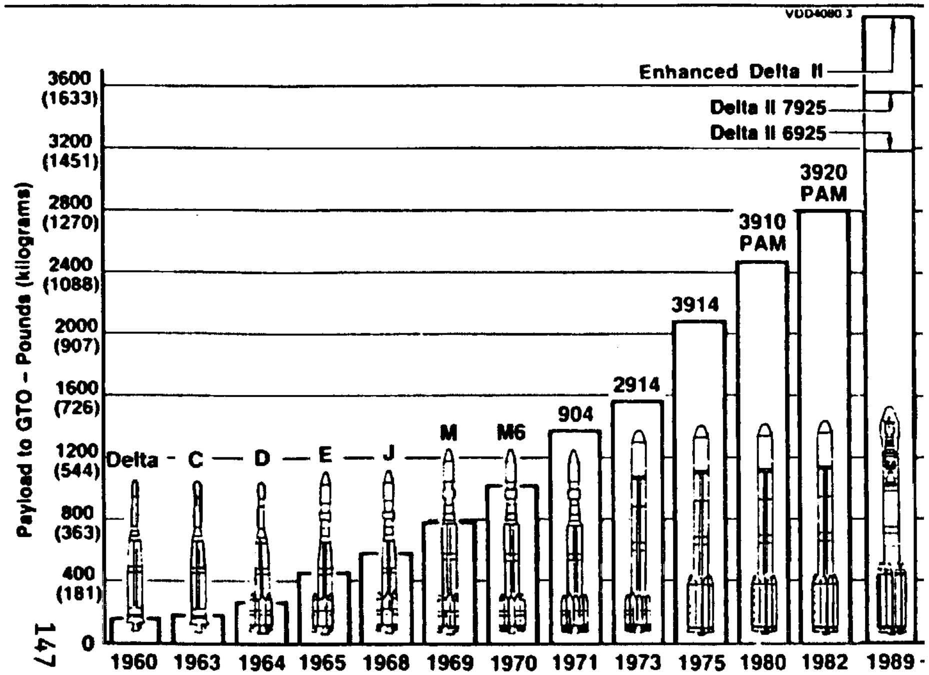
THE RECORD, 92% SUCCESSFUL

	ECHO •	52	INTEL IID (F-4)	103	WESTAR B
2	ECHO-1A	53	OSO D	104	ITOS-G
3	TIROS-A2	54	TOS D	105	SKYNET IIB
4	EXPL-X (P-14)	55	PIONEER C	106	SYMPHONIE A
5	TIROS-A3	56	GEOS B	107	LANDSAT 2
6	EXPL-XII (S-3)	57	RAE A	108	SMS B
7	TIROS-4 (D)	58	TOS E	109	GEOS C
8	OSO-1 (S-3)	59	INTEL IIIA (F-1) •	110	TELESAT C
9	ARIEL (S-51 UK1)	60	PIONEER D	111	NIMBUS F
10	TIROS-5 (E)	61	HEOS A	112	OSO I
11	TELSTAR 1 (TSXI)	62	TOS F (ESSA 8)	113	COS B
12	TIROS 6 (F)	63	INTEL IIIC (F-2)	114	SYMPHONIE B
13	EXPL-XIV (S-3A)	64	OSO F	115	AE D
14	EXPL-XV (S-3B)	65	ISIS-A	116	GOES A
15	RELAY A-15	66	INTEL IIIB (F-3)	117	AE E
16	SYNCOM A-25	67	TOS G	118	RCA A
17	EXPL-XVII (S-6)	68	INTEL IIID (F-4)	119	CTS
18	TELSTAR 2 (TSX2)	69	IMP G	120	MARISAT A
19	TIROS 7 (G)	70	BIOS D	121	RCA B
20	SYNCOM B (A-26)	71	INTEL IIIE (F-5) •	122	NATO IIIA
21	EXPL XVIII (IMPA)	72	OSO G	123	LAGEOS
22	TIROS 8 (H)	73	PIONEER E •	124	MARISAT B
23	RELAY II (A-16)	74	SKYNET A	125	PALAPA A
24	S-66 •	75	INTEL IIIF (F-6)	126	ITOS H
25	SYNCOM C	76	TIROS M	127	MARISAT C
26	IMP-B •	77	NATO A	128	NATO IIIB
27	S-3C	78	INTEL IIIG (F-7)	129	PALAPA B
	TIROS I (Eye)	79	INTEL IIIH (F-8)	130	ESRO GEOS •
29	OSO-B2	80	SKYNET B	131	GOES B
30	COMSAT HS303A	81	ITOS A	132	GMS
31	IMP-C	82	NATO B	133	SIRIO
32	TIROS OT 1	83	IMP I	134	OTS •
33	OSO-C •	84	ISIS B	135	ISEE A/B
34	GEOS-A	85	OSO H •	136	METEOSAT
35	PIONEER-A	86	ITOS B	137	CS
36	OT-3	87	HEOS A2	138	IUE
37	OT-2	88	TD 1A	139	LANDSAT 3
38	AE-B	89	ERTS A	140	BSE
39	IMP D	90	IMP H	141	OTS 2
40	PIONEER B	91	ITOS-D	142	GOES C
41	TOS A	92	TELESAT A	143	ESA GEOS 2
42	INTEL IIA (F-1)	93	NIMBUS E	144	ISEE C
43	BIOS A	94	TELESAT B	145	NIMBUS-G
44	INTEL IIB (F-2)	95	RAE-B	146	NATO IIIC
45	TOS B	96	ITOS-E •	147	TELESAT D
46	OSO E1	97	IMP J	148	SCATHA
47	INTEL IIC (F-3)	98	ITOS-F	149	WESTSTAR-C
48	TOS C	99	AE-C	150	RCA -C
49	IMP F	100	SKYNET IIA •		
50	AIMP E	101	WESTAR A		
51	BIOS B	102	SMS A		• Launch Failures

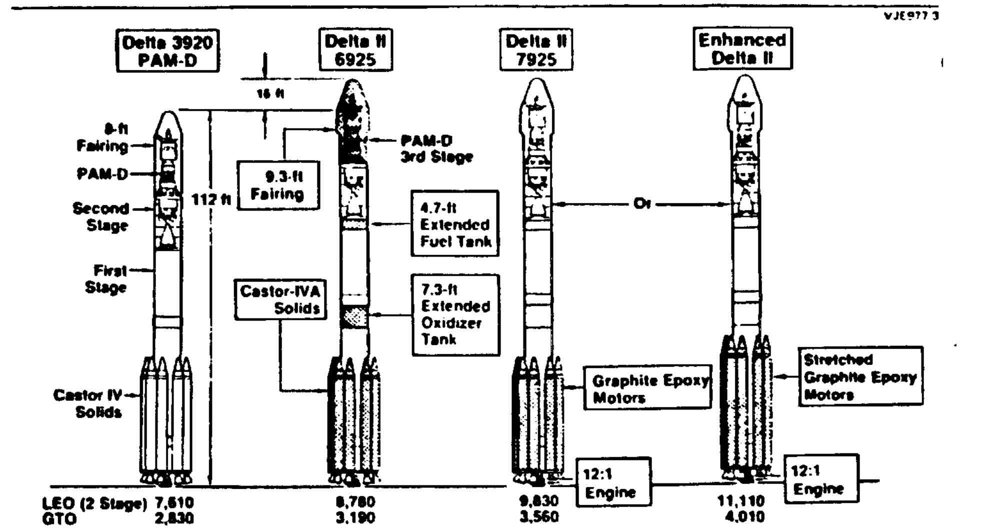
T. /, the Delta can place over 2,100 pounds into geosynchronous transfer orbit, over 20 times its original capability. And with the Delta, spacecraft can be placed into a variety of orbits. These range from the low earth orbit to the geosynchronous orbit at an altitude of 22,300 miles where the spacecraft matches pace with the rotating earth to remain "on station" over the same point above the equator.



DELTA 1979

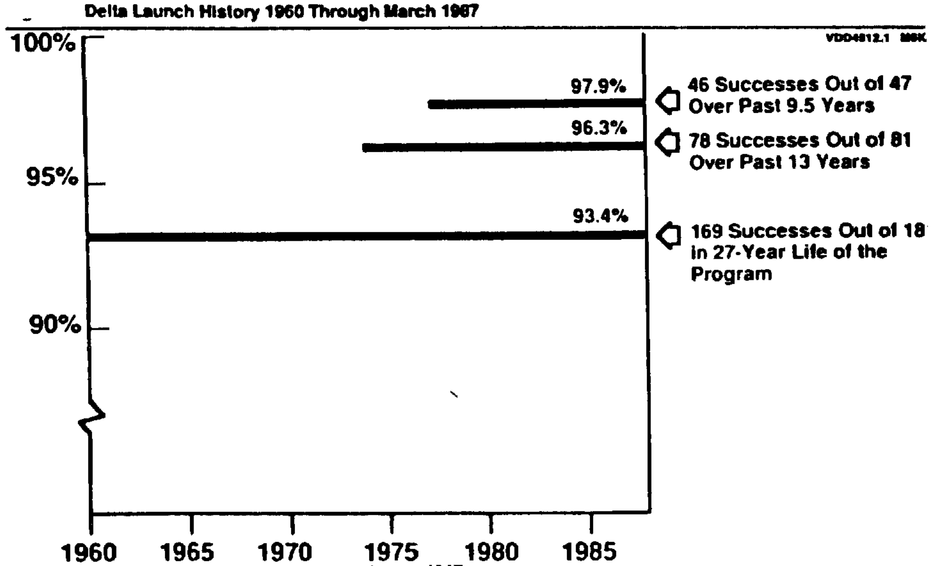


History of Delta Growth

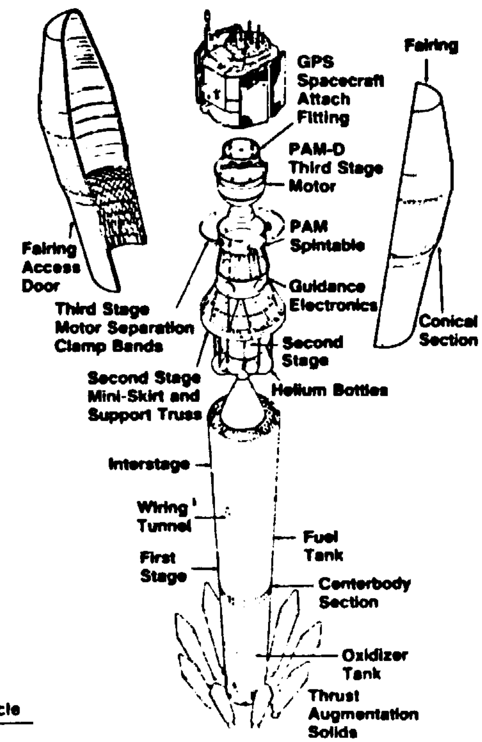


Launch Vehicle Configurations

Delta Launch History 1960 Through March 1987



Delta Reliability History Through March 1987



Delta II Launch Vehicle

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6.7.2 ATLAS / CENTAUR

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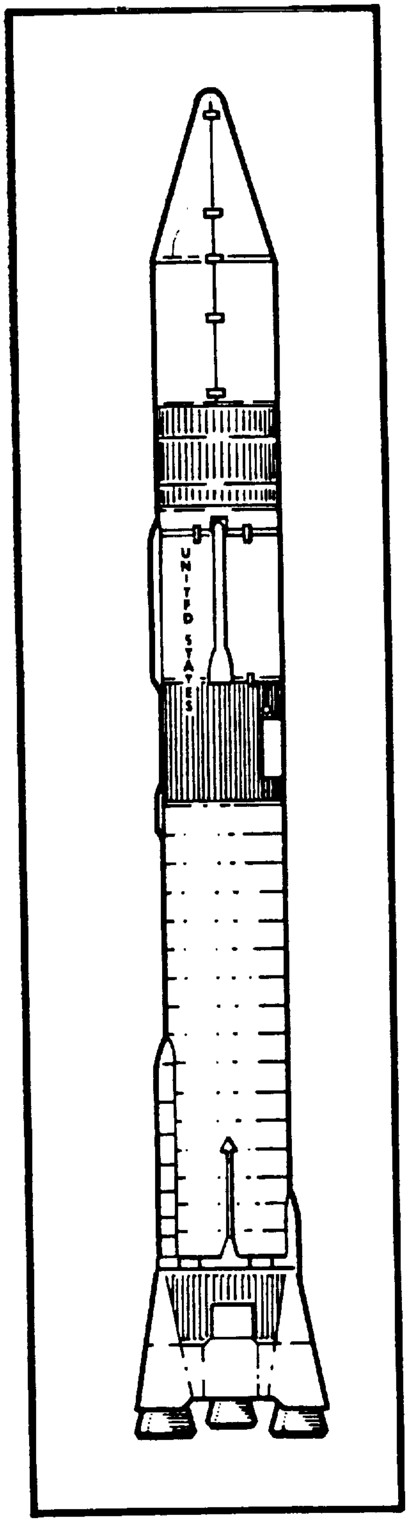

ATLAS/CENTAUR

41.9 METERS (137.6 FEET) TALL – 3 METERS (10 FEET) IN DIAMETER

WITH PAYLOAD, WEIGHS APPROXIMATELY 163,523 KILOGRAMS (360,500 POUNDS) AT LIFTOFF

ATLAS THRUST, 1,950,074 NEWTONS (438,416 POUNDS) AT LIFTOFF

CENTAUR THRUST, 146,784 NEWTONS (33,000 POUNDS) IN A VACUUM FOR 7 1/2 MINUTES

Atlas/Centaur vehicles are built by General Dynamics/Convair (GD/C), and launched by a combined NASA/GD/C team. This two-stage, liquid-fueled vehicle has been used to launch a variety of scientific and technological spacecraft. These have included Surveyors to the moon, Mariners to Venus, Mercury, and Mars, and Pioneers to Jupiter/Saturn. It has placed Applications Technology Satellites, and COMSTAR, INTELSAT, and FLTSATCOM communications satellites, into geosynchronous transfer orbits. The Atlas/Centaur is the most powerful unmanned vehicle now launched by NASA. In 1984 it was upgraded by lengthening the Atlas stage to provide larger propellant tanks. The Centaur stage has been improved by substituting attitude control thrusters powered by hydrazine (used as a mono-propellant) for ones powered by hydrogen peroxide, and replacing the oxygen and hydrogen propellant pumps by pressure-fed systems.

The 23.3-meter (76.3-foot) long first stage is an uprated version of the flight-proven Atlas vehicle used in the national space program since 1959. The Rockwell International/Rocketdyne MA-5 engine system burns RP-1, a highly refined kerosene, and liquid oxygen. The MA-5 utilizes two main engines, a 1,679,120 Newtons (377,500 pounds) thrust booster engine with two thrust chambers, and a smaller sustainer with a single thrust chamber that produces 266,900 Newtons (60,000 pounds) thrust. The sustainer nozzle is located between the two larger ones of the booster engine. Two small vernier engines which help control the vehicle in flight are also burning at liftoff, for a total thrust of 1,950,074 Newtons (438,416 pounds). Total weight at liftoff is about 163,523 kilograms (360,500 pounds).

An unusual feature of the Atlas vehicle is its "stage-and-a-half" construction. All five thrust chambers are burning at liftoff. After more than 2.5 minutes of flight the booster engine cuts off. This engine and its supporting structures are jettisoned, deleting a large portion of the structural weight of this stage. The sustainer and vernier engines continue to burn until the propellants are gone, at about 4.5 minutes. This means an Atlas retains most of the weight reduction advantage gained by jettisoning a used-up stage, but does not have to ignite its engines in flight, as a separate stage must.

The only radio frequency system on the Atlas is a range safety command system, consisting of two receivers, a power control unit, and a destruct unit. The Atlas can be destroyed in flight by ground control if necessary, but otherwise receives all its control directions from the Centaur stage.

The Centaur stage sits above the Atlas, on a barrel-shaped interstage adapter. The Atlas and Centaur separate two or three seconds after the Atlas burns out. Eight small retrorockets near the bottom of the Atlas fuel tank then back this stage away from the Centaur.

The Centaur stage is 9.1 meters (30 feet) in length without the fairing on top. Exclusive of payload, it weighs about 17,700 kilograms (39,000 pounds) when loaded with propellants. The main propulsion system consists of two Pratt & Whitney engines burning liquid oxygen and liquid hydrogen, producing 146,784 Newtons (33,000 pounds) thrust in the vacuum of space in which they are designed to operate. These engines can be stopped and restarted, allowing the Centaur to coast to the best point from which to achieve its final trajectory before igniting for another burn. While coasting, the stage is controlled by 12 small thruster engines, powered by hydrazine. These hold the stage steady and provide a small constant thrust to keep the propellants settled in the bottom of their tanks, a necessity for a second or third burn.

A cylindrical nose fairing with a conical top sits on the Centaur and protects the spacecraft. Total vehicle height is 41.9 meters (137.6 feet). Both stages are three meters (10 feet) in diameter.

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The Centaur electronic packages are mounted in a circle around a conical equipment module, located above the upper tank. An adapter on top of this module connects to the payload adapter on the bottom of the spacecraft. These electronic packages provide an integrated flight control system which performs the navigation, guidance, autopilot, attitude control, sequence of events, and telemetry and data management functions for both the Atlas and Centaur stages. The heart of this system is a Digital Computer Unit (DCU), built by Teledyne. The DCU sends commands to control most planned actions, including all but items one, two, and five in the table following. The DCU receives guidance information from a combination of sensors called the Inertial Measurement Group, built by Honeywell, and sends steering commands to all Atlas and Centaur engines. The Centaur also has a ground-controlled destruct system similar to that on the Atlas, in case the vehicle must be destroyed in flight.

The Centaur uses the most powerful propellant combination available, has a light-weight structure, and an engine burn time of up to 7 1/2 minutes, the longest of any upper stage now in service. This gives it the most total energy for its size of any stage yet built.

The following table provides a list of the major events that will occur during the flight.

Event	Time After Liftoff	Altitude (Kilometers)	Altitude (Miles)	Distance Downrange (Kilometers)	Distance Downrange (Miles)	Velocity (Kilometers)	Velocity (Miles)
Liftoff	T+0	---	---	---	---	---	---
Atlas Booster Engine Cutoff	2 min 35 sec	60	37	90	56	9,011	5,599
Jettison Atlas Booster Engine	2 min 39 sec	63	39	98	61	9,125	5,670
Jettison Centaur Insulation Panels	3 min 0 sec	82	51	151	94	9,746	6,056
Jettison Nose Fairing	3 min 44 sec	114	71	277	172	11,312	7,029
Atlas Sustainer/Vernier Engines Cutoff	4 min 32 sec	143	89	436	271	13,662	8,489
Atlas/Centaur Separation	4 min 35 sec	143	89	444	276	13,670	8,494
First Centaur Main Engines Start	4 min 45 sec	150	93	483	300	13,646	8,479
Centaur Main Engines Cutoff	9 min 56 sec	164	102	2,094	1,301	26,799	16,652
Second Centaur Main Engines Start	23 min 58 sec	161	100	8,230	5,114	26,847	16,682
Second Centaur Main Engines Cutoff	25 min 35 sec	177	110	9,035	5,614	35,414	22,005
Centaur/Spacecraft Separation	27 min 50 sec	288	179	10,309	6,406	35,056	21,783

These numbers may vary, depending on exact launch date, launch time, and spacecraft weight.

NOTE: The final velocity of 35,414 kilometers (22,005 miles) per hour places the spacecraft in a transfer orbit, with an apogee of 35,782 kilometers (22,234 miles) and a perigee of about 161 kilometers (100 miles). The Air Force then assumes control of the spacecraft. At an apogee chosen by Air Force controllers, the on-board apogee kick-motor will be fired to circularize the orbit at geosynchronous altitude, about 35,789 kilometers (22,238 miles) above the equator. It will then be "drifted" to its assigned place in the FLTSATCOM global network. The spacecraft will have a final velocity of about 11,071 kilometers (6,879 miles) per hour. It will complete one orbit every 24 hours, and so move back and forth above the same area on both sides of the equator.

General Dynamics Cites Launch Candidates for Atlas G/Centaur

San Diego—General Dynamics has identified 45 satellites as high-priority objectives in its renewed marketing campaign for commercial launches between 1989 and 1994 with an Atlas G/Centaur, which will have a payload fairing sized to accommodate space shuttle and Ariane 4-class payloads.

The company is talking to 10 potential customers about possible launch of about 15 spacecraft during the five-year period, Alan M. Lovelace, general manager of General Dynamics' space systems division, said. Nearly all of the satellites are communications spacecraft, and about 70% are domestic payloads.

General Dynamics' market projections show there are 27 firm payloads to be launched during the five-year period in the payload weight class of the Atlas G/Centaur—3,500-5,200 lb. to geosynchronous transfer orbit.

In addition to the 27 firm spacecraft, there are an estimated 22 additional satellites that are planned replacements for existing spacecraft and nine more that are "possible" payloads. The total of 58 satellites, uncommitted to a launch vehicle, include government satellites and domestic and international commercial payloads.

General Dynamics reevaluated the commercial launch vehicle market after the company was not selected to develop the Air Force's medium-launch vehicle (MLV). Company officials said a launch rate of three satellites per year beginning in 1989 would be an acceptable rate for the Atlas/Centaur in launches from Pad 36B at Cape Canaveral AFS, Fla.—which could support up to five launches with a surge to six launches per year.

Launch Pad 36A, which was used for development work on the shuttle-Centaur program, could be reactivated for Atlas launches as a growth option.

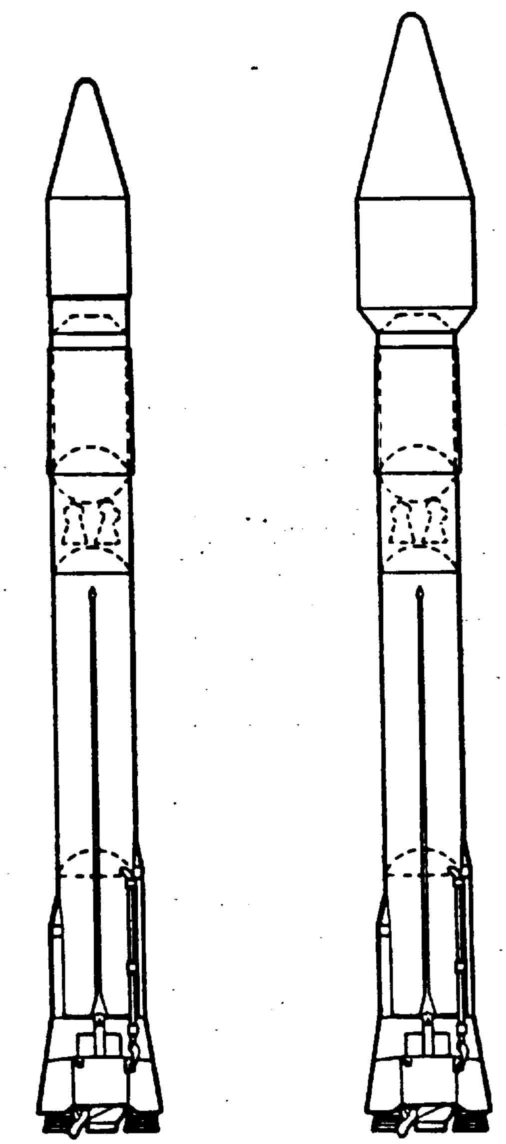
Lovelace said General Dynamics has received a memorandum of understanding from the Air Force which the Air Force said should enable the company to proceed with commercial launch vehicle planning and more detailed discussions with potential customers.

In addition to the Air Force commercialization agreement, General Dynamics expected formal approval last week of an agreement with NASA headquarters on issues such as tooling, equipment, manufacturing, financial arrangements and liability.

An ancillary agreement for launch services may be completed in April.

The Atlas G/Centaur will be offered with payload fairing diameters of 10 ft., 10.8 ft. and 13.8 ft. The 10-ft. shroud is the same size as the present fairing, while the 10.8-ft. shroud has been sized to accommodate payload assist module (PAM-D2) class payloads and payloads designed for Ariane 2 and 3 fairing sizes.

Payload weight performance with the largest fairing would be reduced by about 400 lb. as a result of increased aerodynamic drag and the mass of the larger structure. □



Comparison of present General Dynamics Atlas G/Centaur launch vehicle, left, and the planned Atlas G/Centaur booster with a 13.8-ft.-dia. payload fairing is shown in drawing. The new launch vehicles, designed to boost payloads of up to 4,800 lb. to geosynchronous transfer orbit, would be available beginning in 1989.

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6.7.3 TITAN

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MARTIN MARIETTA

Denver Division
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Denver, Colorado 80201
January 197[illegible]

There are four versions of the Titan III launch vehicle. The IIIB and IIID are launched from Vandenberg Air Force Base, and the IIIC and IIIE from Cape Canaveral. The core vehicle with SRMs is the most powerful launch vehicle developed by the Air Force. The Titan IIIE, with Centaur payload shroud four feet wider than booster stages, has a hammerhead shape that is unique in today's launch vehicles.

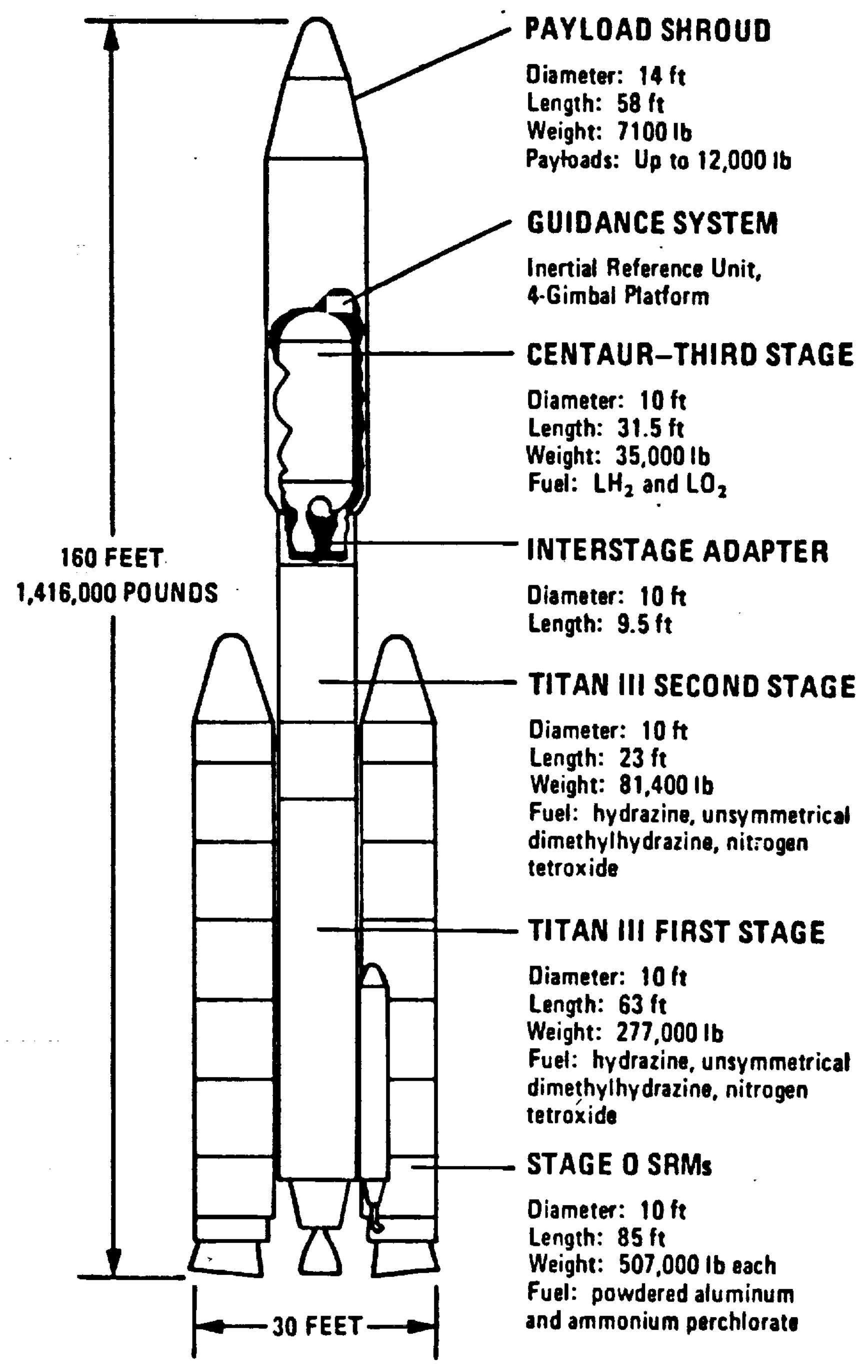
Two strap-on solid fuel rockets (Stage O): two motors, powdered aluminum and ammonium perchlorate fuel, burn duration 122 sec, thrust 2.4 million lb.

Two-stage liquid propulsion core vehicle: Stage I, two engines, hydrazine, unsymmetrical dimethylhydrazine, and nitrogen tetroxide fuel, burn time 148 sec, thrust 520,000 lb. Stage II, one engine, hydrazine, unsymmetrical dimethylhydrazine, and nitrogen tetroxide fuel, burn time 208 sec, thrust 101,000 lb.

High-energy restartable upper stage developed by NASA: two engines, liquid hydrogen and liquid oxygen fuel, capability of multiple starts, total burn time 433 sec, thrust 30,000 lb.

Centaur Standard Shroud: 58 ft long and 14 ft diameter, required for enclosing Viking spacecraft and Centaur for liftoff and ascent; developed by NASA.

Inertial reference unit with four-gimbal, all-attitude-stable platform, stabilized by three gyros; advanced high-speed digital computer.



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MARTIN MARIETTA

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FACT SHEET
TITAN II Space Launch Vehicle

PROGRAM	Titan II space launch vehicle
CUSTOMER	U.S. Air Force, Space Division Los Angeles, California
CONTRACT VALUE	$615 million
CONTRACT STATUS	Martin Marietta's Space Launch Systems company is under contract to refurbish 13 government-owned Titan II ICBMs for use as space launch vehicles. The contract, awarded in January 1986, runs through September 1995.
MARTIN MARIETTA ROLE	Martin Marietta is converting the Titan IIs from ICBMs to space launch vehicles. Tasks include modifying the forward structure of the second stage to accommodate a 10-foot diameter payload fairing with variable lengths; manufacturing the new fairings plus payload adapters; refurbishing the Titans' liquid rocket engines; upgrading the inertial guidance systems; developing command, destruct and telemetry systems; modifying Vandenberg Air Force Base Space Launch Complex-4 West to conduct the launches; and performing payload integration.
DESCRIPTION	The Titan II space launch vehicle is a modified Titan II ICBM. It consists of two stages, a payload adapter and payload fairing.
PURPOSE	To provide low-cost, low- to medium-weight launch capability into low polar orbit.
FIRST STAGE	Length: 70 feet Diameter 10 feet Engine Thrust: 430,000 pounds

(more)

SECOND STAGE	Length: 40 feet Diameter: 10 feet Engine Thrust: 100,000 pounds
GUIDANCE	Inertial with digital computer Subcontractor: Delco Electronics
PAYLOAD FAIRING	Diameter: 10 feet Lengths: 20 to 30 feet Skin and stringer construction, tri-sector design Subcontractor: McDonnell Douglas
LIQUID ROCKET ENGINES	Refurbished Titan II ICBM engines Subcontractor: Aerojet TechSystems Co.
CAPABILITY	The Titan II will be able to lift about 4,800 pounds into a 100 nautical mile circular orbit.
BACKGROUND	Martin Marietta built more than 140 Titan ICBMs, once the vanguard of America's nuclear deterrent force, for the Air Force. Titan IIs also were flown as space launch vehicles in NASA's Gemini manned space program in the mid-1960s. Deactivation of the Titan II ICBM system began in July 1982. The last missile was taken from its silo at Little Rock Air Force Base, Arkansas, on June 23, 1987. Deactivated missiles are in storage at Norton Air Force Base in San Bernadino, California. Martin Marietta is responsible for transporting the Titan IIs from California to its facilities in Denver.
TIMETABLE	The Air Force requires an initial launch capability of a Titan II space launch vehicle in April 1988 from Vandenberg Air Force Base, California, with subsequent launches continuing into 1995.

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September 1987

MARTIN MARIETTA
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MARTIN MARIETTA

IBLIC RELATIONS (303) 977-5364

FACT SHEET
TITAN 34D

PROGRAM	Titan 34D
CUSTOMER	U.S. Air Force, Space Division Los Angeles, California
COMPANY ROLE	Martin Marietta, along with its associates, designs and builds the Titan 34D for the Air Force. Martin Marietta is responsible for the first and second stages, along with systems integration and launch support services.
CONTRACT STATUS	The company has built and delivered 15 Titan 34Ds to the Air Force.
DESCRIPTION	The Titan 34D is a space launch vehicle in the Titan launch vehicle family that has been the Air Force's principal launch system for 20 years.

The common core vehicle consists of two liquid-propellant booster stages that are the central propulsion element. Twin 10.2-foot diameter solid-propellant rocket motors are attached to each side of the first stage and provide additional thrust during the boost phase. The Titan 34D uses five-and-one-half-segment solid rocket motors.

The Titan 34D currently flies with a 10-foot diameter or 10.5-foot diameter payload fairing (payload enclosure). The length of the payload fairing varies from 15 feet to 60 feet, depending on the payload.

The Titan 34D accommodates a variety of specialized upper stages. It is currently launched using inertial guidance with a Transtage, or using radio guidance with no upper stage. It can be configured for a variety of orbits, multiple payloads, and complex mission operations.

(more)

LAUNCH SITES	The Titan 34D is launched from both Vandenberg Air Force Base, California, and Cape Canaveral Air Force Station, Florida.	
OVERALL LENGTH	Up to 161.9 feet (depending on configuration)	
OVERALL WEIGHT	Up to 759.8 tons, plus payload	
THRUST AT LIFTOFF	2.8 million pounds	
SOLID ROCKET MOTORS (2)	Length:	90.4 feet
	Diameter:	10.2 feet
	Motor Thrust:	1.4 million pounds per motor
	Weight:	552,000 pounds per motor
	Propellants:	solid
	Contractor:	United Technologies
FIRST STAGE	Length:	77.8 feet
	Diameter:	10 feet
	Engine Thrust:	529,000 pounds
	Propellants:	liquid*
	Stage Contractor:	Martin Marietta
SECOND STAGE	Length:	31 feet
	Diameter:	10 feet
	Engine Thrust:	101,000 pounds
	Propellants:	liquid*
	Stage Contractor:	Martin Marietta
PAYLOAD FAIRING	Diameter:	10 feet
	Lengths:	15 to 60 feet
	Diameter:	10.5 feet
	Lengths:	40 to 55 feet

CAPABILITIES

The Titan 34D can deploy single or multiple satellites to low, transfer, or geosynchronous Earth orbits, as well as on deep space or interplanetary flights. It also offers compatibility with many Shuttle payloads.

The Titan 34D can deliver up to 31,650 pounds (14,360 kilograms) into low-Earth orbit when launched from Cape Canaveral, Florida. Using a Transtage, it can place 4,200 pounds (1,905 kilograms) into geosynchronous orbit.

When launched from Vandenberg AFB, California, the Titan 34D can deliver a 27,000-pound (12,247-kilogram) spacecraft into a 100-nautical-mile polar orbit.

*Fuel: Aerozine 50
Oxidizer: nitrogen tetroxide

(more)

PAST PERFORMANCE

The first launch of a Titan 34D, with a payload of two high-performance military communications satellites, occurred in October 1982. As of January 1988, there had been 11 Titan 34D launches.

BACKGROUND

The U.S. Air Force Titan I intercontinental ballistic missile (ICBM) system was the first product of Martin Marietta in Denver, Colorado. Titan I was followed by the Titan II ICBM, which evolved into a space launch vehicle in the 1960s. Man-rated for the Gemini program, Titan II launched the space program's 10 two-man Earth-orbiting missions during 19 months in 1965 and 1966.

Titan III began service in 1964. To date it has delivered more than 200 payloads into Earth orbits or on missions to the Sun and planets. Titan IIIs were employed to launch the Viking spacecraft to Mars in 1975 and the Voyager deep-space probes in 1977.

In June 1977, the Air Force awarded Martin Marietta a contract for the Titan 34D.

ASSOCIATE CONTRACTORS

United Technologies, Chemical Systems Division (solid rocket motors)
Aerojet TechSystems Co. (liquid-propellant engines)
General Motors' Delco Systems Operations (inertial guidance components for Transtage)
McDonnell Douglas Astronautics Co. (payload fairing for East Coast launches)
Western Electric Corp. (radio guidance system)
Lockheed Missiles & Space Co., Inc. (Agena upper stage and payload fairing for West Coast launches and the Agena upper stage)

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January 1988

MARTIN MARIETTA
SPACE LAUNCH SYSTEMS
P.O. Box 179, DENVER, COLORADO 80201

MARTIN MARIETTA

BLIC RELATIONS (303) 977-5364

FACT SHEET
TITAN IV

PROGRAM	Titan IV
CUSTOMER	U.S. Air Force, Space Division Los Angeles, California
CONTRACT VALUE	Approximately $4.4 billion
MARTIN MARIETTA ROLE	Martin Marietta Space Launch Systems is responsible to the Air Force for development, production, and launch services for the Titan IV space launch vehicle.
CONTRACT STATUS	In February 1985, Martin Marietta was chosen by the Air Force to build and launch ten Titan IVs. The program was expanded to 23 vehicles in August 1986.
DESCRIPTION	The Titan IV is a growth version of the Titan 34D space launch system, with stretched first and second stages, seven-segment solid-propellant rocket motors, and a 16.7-foot diameter payload fairing. The Titan IV launch system includes a modified Centaur G-prime upper stage, and also may be flown with an Inertial Upper Stage (IUS), or no upper stage. Overall length of the system is 204 feet when flown with an 86-foot payload fairing. In 1991, upgraded three-segment solid rocket motors will be added as an element of the Titan IV system.
PAYLOAD CAPABILITY	The Titan IV Centaur is capable of placing 10,000-pound payloads into geosynchronous orbit, 22,300 miles above the Earth. The Titan IV system also is capable of placing 39,000 pounds into a low-Earth orbit at 28.6 degrees inclination or 32,000 pounds into a low-Earth polar orbit. The addition of the solid rocket motor upgrade will enhance performance by approximately 25 percent.
LAUNCH SITES	The Titan IV will be launched from Cape Canaveral Air Force Station, Florida, and Vandenberg Air Force Base, California.

(more)

SOLID ROCKET MOTORS (2)	Length:	112 feet
	Diameter:	10 feet
	Motor Thrust:	1.38 million pounds per motor (peak vacuum)
	Weight:	692,000 pounds
	Propellants:	solid--polybutadiene acrylic acid acrylonitrile (PBAN) composite which uses powdered aluminum fuel and ammonium perchlorate oxidizer
	Contractor:	Chemical Systems Division, United Technologies Corp.
UPGRADED SOLID ROCKET (2) MOTORS	Length:	112.4 feet
	Diameter:	126 inches
	Motor Thrust:	1.7 million pounds per motor (peak vacuum)
	Weight:	759,000 pounds
	Propellant:	solid, 88 percent hydroxyl terminated polybutadiene
	Contractor:	Hercules Aerospace
FIRST STAGE	Length:	86.5 feet
	Diameter	10 feet
	Engine Thrust:	548,000 pounds (full duration average)
	Propellants:	hypergolic liquid--Aerozine-50 (hydrazine and unsymmetrical dimethyl-hydrazine) fuel and nitrogen tetroxide oxidizer
	Contractor:	Martin Marietta
SECOND STAGE	Length:	32.7 feet (bottom of engine nozzle to top of forward skirt)
	Diameter:	10 feet
	Engine Thrust:	105,000 pounds (full duration average)
	Propellants:	hypergolic liquid--Aerozine-50 and nitrogen tetroxide
	Contractor:	Martin Marietta
MODIFIED CENTAUR G-PRIME UPPER STAGE	Length:	29.45 feet
	Diameter:	170 inches
	Engine Thrust:	33,000 pounds
	Propellants:	cryogenic--liquid oxygen and liquid hydrogen
	Stage Contractor:	General Dynamics Space Systems

(more)

INERTIAL UPPER STAGE	Length:	17 feet
	Diameter:	flares from 90 to 114 inches
	Engine Thrust:	42,000 pounds/17,500 pounds
	Propellants:	solid--hydroxyl terminated polybutadiene
	Contractor:	Boeing Aerospace Co.
GUIDANCE	Inertial with digital computer	
	Contractor:	Delco Systems Operations, General Motors Corp.
PAYLOAD FAIRING	Length:	56-86 feet
	Diameter:	200 inches
	Aluminum isogrid construction, trisector design	
	Contractor:	McDonnell Douglas Astronautics Co.
LAUNCH WEIGHT	Approximately 1.9 million pounds	

BACKGROUND

The Titan IV is the latest addition to a family of Titan launch vehicles that has compiled an unsurpassed record. The Titan III has successfully completed 131 of 136 operational launches for a 96.3 percent success rate.

TIMETABLE

The Air Force plans the initial launch of a Titan IV in late 1988, with a projected launch rate of 10 vehicles per year in the 1995 fiscal year.

TEAM MEMBERS

Subcontractors

*Aerojet TechSystems Co., Sacramento, CA--liquid rocket engines
*Chemical Systems Division, United Technologies Corp., San Jose, CA--solid rocket motors
*Hercules Aerospace Co., Magna, UT--solid rocket motor upgrade
*Delco Systems Operations, General Motors Corp., Goleta, CA--inertial guidance
*General Dynamics Space Systems, San Diego, CA--modified Centaur G-prime upper stage
*McDonnell Douglas Astronautics Co., Huntington Beach, CA--payload fairing
*Spacecraft, Inc., Huntsville, AL--instrumentation
*Cincinnati Electronics Corp., Cincinnati, OH--command receivers

Associate Contractor

*Boeing Aerospace Co., Seattle, WA--IUS

MARTIN MARIETTA
COMMERCIAL TITAN, INCORPORATED
P.O. Box 179, DENVER, COLORADO 80201

MARTIN MARIETTA

'UBLIC RELATIONS (303) 977-5364

FACT SHEET
COMMERCIAL TITAN

PROGRAM

Commercial Titan

COMPANY ROLE

Martin Marietta Commercial Titan, Inc., is offering a version of the Titan III space launch vehicle for launches of commercial satellites. The Commercial Titan can place payloads in excess of 31,000 pounds into low-Earth orbit, and launch most large communications satellites two at a time.

CUSTOMERS

Martin Marietta signed its first contract for Commercial Titan launch services on August 10, 1987, with the International Telecommunications Satellite Organization (INTELSAT). The contract calls for the launch of two INTELSAT VI communications satellites in 1989 and 1990.

On September 14, 1987, Martin Marietta signed a contract with Hughes Communications, Inc., representing Japan Communications Satellite Company, to launch the JCSAT-2 communications satellite on a Commercial Titan in 1989. JCSAT-2 will be paired with a British military communications satellite in the Skynet 4 series, which Martin Marietta will launch for the British Ministry of Defence.

DESCRIPTION

The Commercial Titan is a member of the Titan launch vehicle series that has been the Air Force's principal launch system for 20 years. Titans also have flown missions for the National Aeronautics and Space Administration.

The common core vehicle consists of two liquid-propellant booster stages that are the central propulsion element. Twin 10.2-foot diameter solid-propellant rocket motors (SRMs) are attached to each side of the core vehicle and provide additional thrust during the boost phase. The Commercial Titan launch vehicle uses five-and-one-half-segment SRMs.

(more)

DESCRIPTION (cont.)

Martin Marietta is using a 13.1-foot diameter payload fairing for the Commercial Titan.

The Commercial Titan launch vehicle can accommodate a variety of specialized upper stages, and can be configured for a variety of orbits, multiple payloads, and complex mission operations.

SOLID ROCKET MOTORS (2)

Length:	90.4 feet
Diameter:	10.2 feet
Motor Thrust:	1.4 million pounds per motor
Weight:	552,000 pounds per motor
Propellants:	UTP-3001B solid
Contractor:	United Technologies

FIRST STAGE

Length:	78.6 feet
Diameter:	10 feet
Engine Thrust:	546,000 pounds
Propellants:	Aerozine 50, nitrogen tetroxide
Stage Contractor:	Martin Marietta

SECOND STAGE

Length:	32.7 feet
Diameter:	10 feet
Engine Thrust:	104,000 pounds
Propellants:	Aerozine 50, nitrogen tetroxide
Stage Contractor:	Martin Marietta

PAYLOAD FAIRING AND EXTENSION MODULE

Diameter:	13.1 feet (4 meters)
Overall Length:	up to 52.5 feet
Contractor:	Contraves AG (for the payload fairing)

AFT PAYLOAD CARRIER

Length:	18.3 feet (5.6 meters) (low-Earth orbit) 16 feet (4.8 meters) (geosynchronous transfer orbit)
Diameter:	13.1 feet (4 meters)
Composition:	Lightweight graphite epoxy

Dornier System GmbH

LAUNCH SITE

Launch Complex 40 and associated processing facilities at Cape Canaveral Air Force Station, Florida.

PAST PERFORMANCE

The first operational launch of a Titan III was on July 29, 1966. As of October 26, 1987, the Titan III had recorded 131 successful flights in 136 operational launches for a 96.3 percent success rate.

(more)

BACKGROUND

The U.S. Air Force Titan I intercontinental ballistic missile (ICBM) system was first produced in 1956 by Martin Marietta in Denver. Titan I was followed by the Titan II ICBM, which evolved into a space launch vehicle in the 1960s. Man-rated for the Gemini program, Titan II launched the space program's 10 two-man Earth-orbiting missions during 19 months in 1965 and 1966.

Titan III began service in 1964 and has delivered more than 200 payloads into Earth orbits or on missions to the Sun and planets. Titan IIIs were employed to launch the Viking spacecraft to Mars in 1975 and the Voyager deep-space probes in 1977.

Martin Marietta currently has three Titan space launch systems in various stages of production or development. They include the Titan IV, the most powerful Titan vehicle which will be used to launch payloads for the Air Force as a complement to the Space Shuttle; the Titan II, which is being converted from deactivated Titan II ICBMs; and the Titan 34D, another version of the Titan III that Martin Marietta builds for the Air Force.

THE TITAN TEAM

United Technologies, Chemical Systems Division (solid rocket motors)
Aerojet TechSystems Co. (liquid-propellant engines)
General Motors' Delco Systems Operations (inertial guidance components)
Contraves AG (payload fairing)
Dornier System GmbH (payload carrier assembly)

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November 1987

6.7.4 SHUTTLE DERIVES (SCE)

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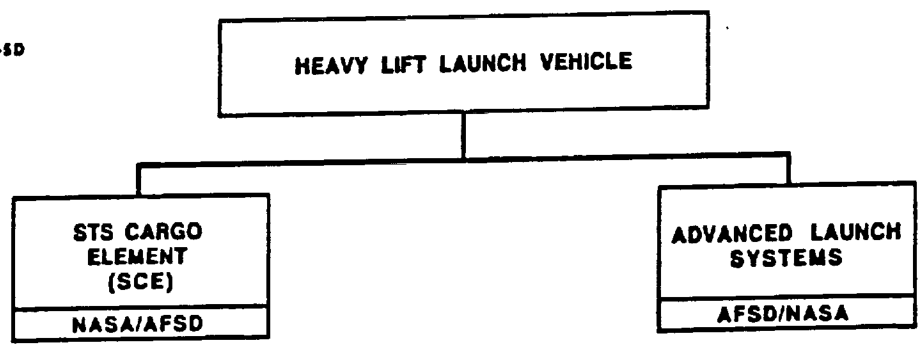
6.7.4 SHUTTLE DERIVES (SCE)

NASA HLLV STATUS
BRIEFING TO DR. FLETCHER

JUNE 1987

HEAVY LIFT LAUNCH VEHICLE OVERVIEW

1-3378-7-5D



- NEAR TERM (92-98) – PHASE B/C
- HIGH RELIABILITY
- EXISTING SYSTEMS & FACILITIES
- LOW DEVELOPMENT COST (89, 90, 91)
- EVOLUTIONARY TEST BED
- LOW COST/lb TO ORBIT
- LOW LAUNCH RATE (2-4/YR)
- LOW LBS/YR TO ORBIT

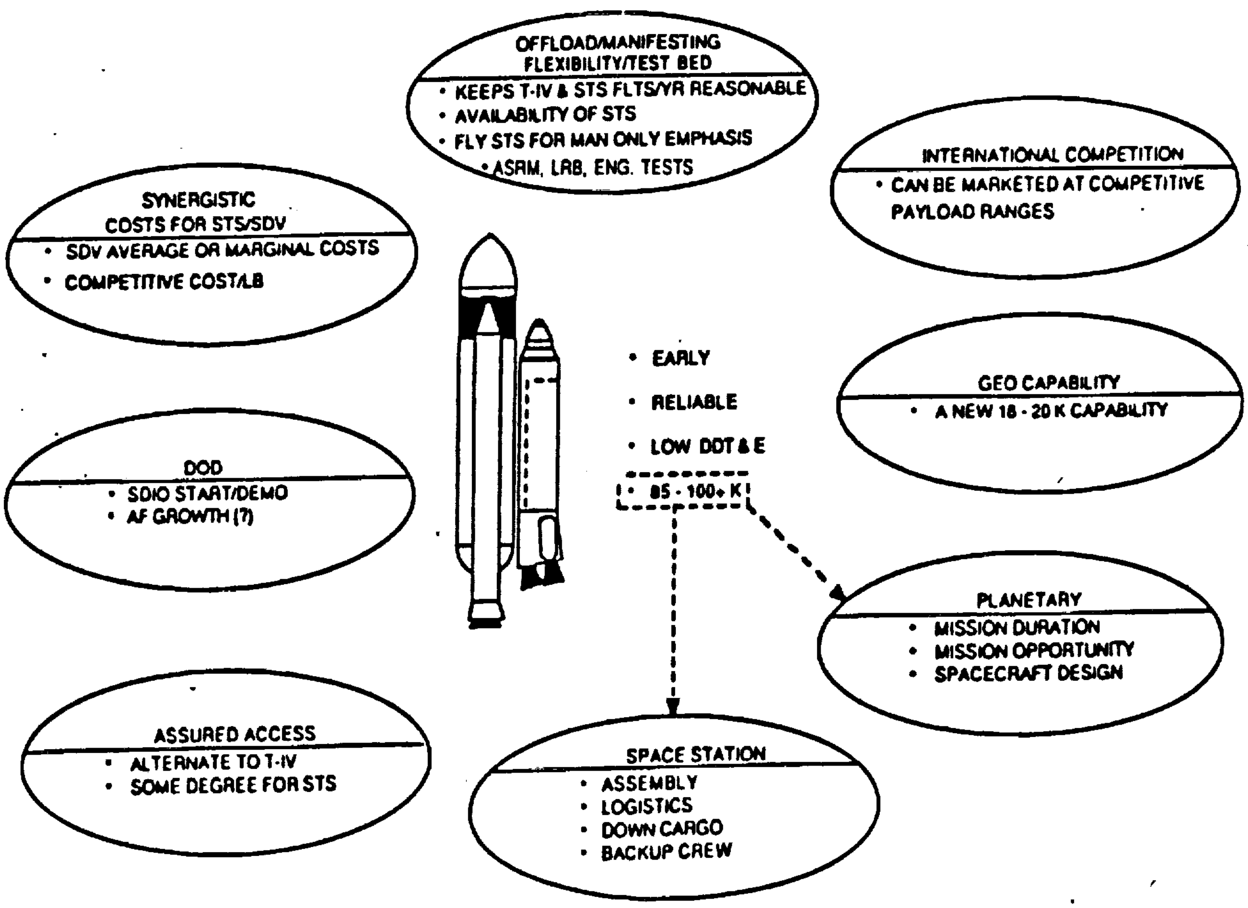
- LONGER TERM – LATE 90's – PHASE A
- HIGH RELIABILITY
- NEW FACILITIES & NEW/EVOLVED SYSTEMS
- HIGH DEVELOPMENT COST-MID 90's
- ADVANCED SYSTEMS
- LOWER COST/lb TO ORBIT
- HIGH LAUNCH RATE
- MILLIONS LBS/YR

SCE-1/Mjh

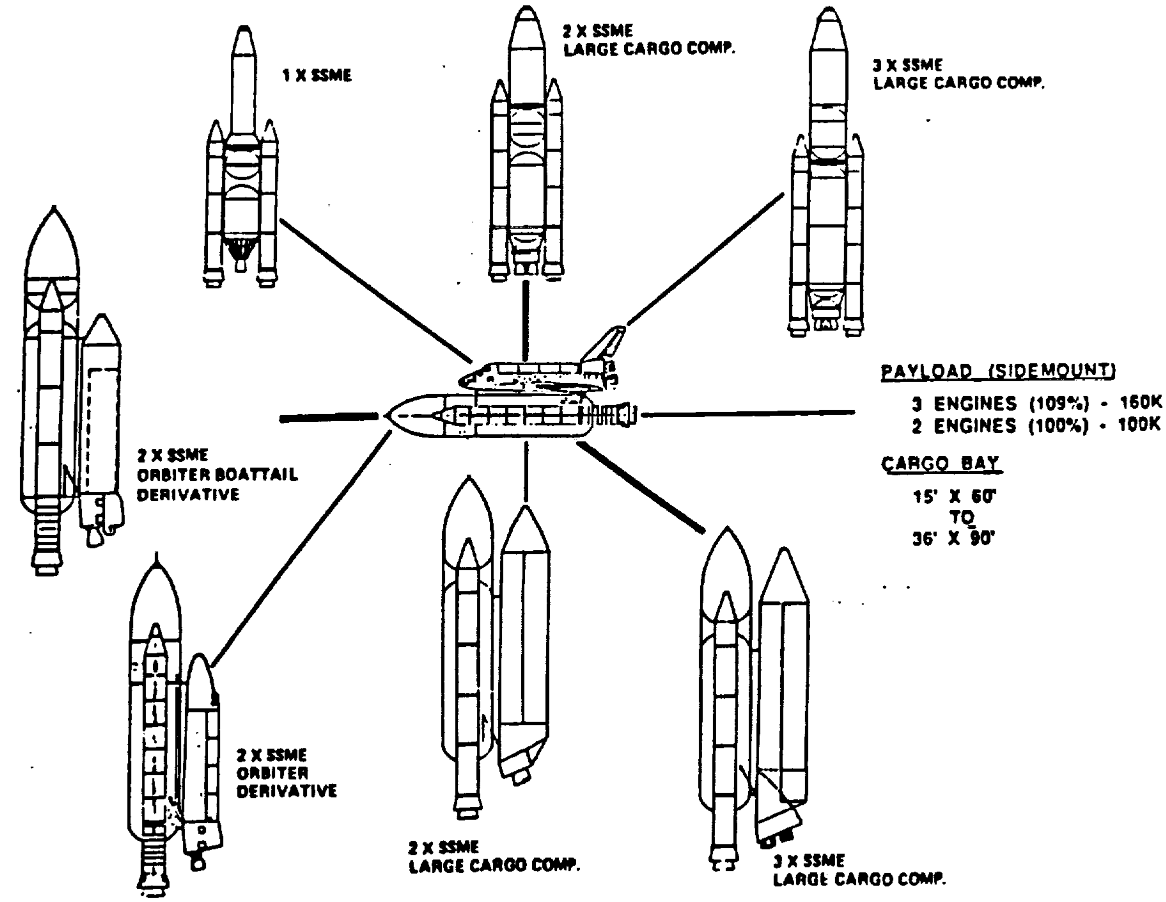
SCE Requirements

- Vehicle Needed in Fleet ASAP - 1992/1993
  - Space Station Assembly & Logistics
  - Enhances Planetary Mission
  - STS Offloading/Manifesting
  - Leadership Initiatives
  - Assured Access for Centaur Class Payloads
  - Test Bed for Items such as ASRM, LRB, New Engines
- OMV Utilized For Payload Deployment/Placement
- Initial Vehicle Flies Expendable Core Used Engines - Refurbished SRB
- Flights - 2-4/Year
- Minimum Performance Required - 85K-220 n.mi. - 28.5 Deg.
- Auxiliary Propulsion for Circularization and Deorbit
- Payload Carrier Volume - Nominal 15'x60' with no Change in Current Attach Points (Orbiter to Booster)
- Unmanned Vehicle - Man Rated
- Launch Capability From ETR or WTR
- Payload Interchangeability Between STS & SCE to be Maintained

SCE VEHICLE REQUIREMENTS 1993-2000



SCE CONFIGURATION OPTIONS



VEHICLE SELECTION

SCE COFIGURATIONS

SIDEMOUNT

- STANDARD SRB
- STANDARD ET
- STANDARD/MODIFIED ORBITER BOATTAIL
- NEW PAYLOAD CARRIER
- STANDARD STS FLIGHT PROFILE
- MINIMIZED FACILITY IMPACTS

INLINE

- STANDARD SRB
- MODIFIED ET
- NEW PAYLOAD SHROUD, PAYLOAD ADAPTER, THRUST STR.
- ET CARRIED TO ORBIT
- MODIFIED FACILITIES

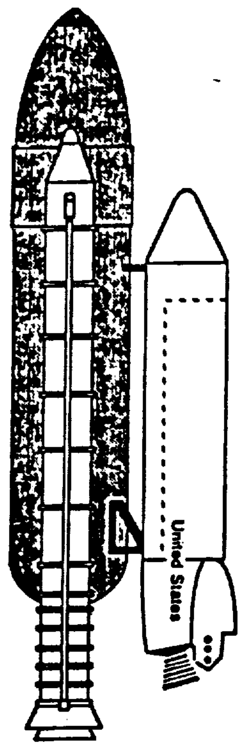
REQUIREMENTS

- NEEDED ASAP
- MINIMUM PERFORMANCE OF 85 KLB TO 220NM/28.5 DEG
- P/L INTERCHANGABILITY WITH STS
- MINIMAL FACILITY IMPACTS
- MINIMUM GOING-IN COST

SCE CHOICE

- SIDEMOUNT
- 2 ENGINE ORBITER BOATTAIL
- 15' X 60' BAY

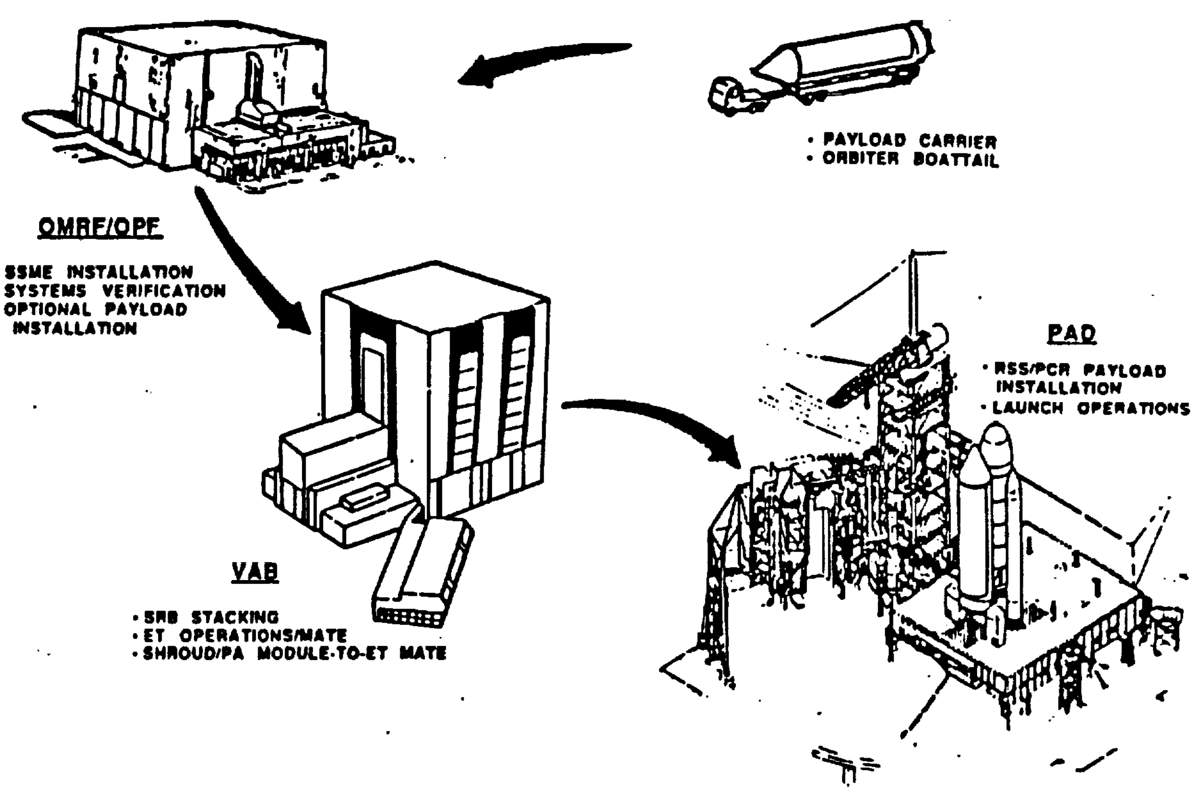
STS CARGO ELEMENT (SCE)



- **STANDARD 4-SEGMENT SRB'S (REUSEABLE)**
- **STANDARD ET (EXPENDABLE)**
- **ORBITER BOATTAIL (EXPENDABLE)**
  - 2 SSME's (Remove SSME #1)
  - Remove Verticle Stabilizer
  - Remove Body Flap
  - Cap SSME #1 Feedlines
  - OMS Pods (Do Not Install OME's, RCS Tanks And 4 RCS Thrusters/Pod)
  - RCS Performs Circularization And Deorbit
  - Cover And Thermally Protect SSME #1 Opening
- **PAYLOAD CARRIER (EXPENDABLE)**
  - New Shroud/Strongback
  - Skin/Stringer/Ringframe Construction Of Al 2219
  - 15' X 72' Useable Payload Space
  - 15' X 60' Changeout On Pad Capability
- **AVIONICS**
  - Uses Mature Design Components From STS And Other Applications
  - Requires Some New Integration And Software
- **PERFORMANCE - ETR - 160 NM/28.5° - 114 KLB**
  - 220 NM/28.5° - 109 KLB

1-2990-7

STS CARGO ELEMENT (SCE)
LAUNCH PROCESSING



Amroc Pursues SDI as First Paying Customer

Los Angeles—The Strategic Defense Initiative Organization is negotiating with American Rocket Co. (Amroc) to carry experiments on the company's first two suborbital launches in the first half of next year, making it likely that SDIO will be Amroc's first paying customer.

The first launch, tentatively set for February from Vandenberg AFB, Calif., is to carry a 220-lb. payload to an altitude of 100 naut. mi., along with flight test instrumentation for the rocket. The second launch, tentatively set for April or May, uses more of the payload space available and has several interesting features. The motor will be shut down in flight, and the payload will separate. The motor will then be restarted and the payload will observe the plume.

The suborbital launch vehicle (SLV) will be a single, 70,000-lb. sea-level-thrust hybrid liquid/solid rocket motor that Amroc plans to use as a building block for its modular orbital launchers (AW&ST Apr. 27, p. 34). The hybrid motor passes liquid oxygen over solid polybutadiene fuel and can be controlled by regulating oxygen flow.

There is no aluminum in the solid fuel, so the motor plume will appear more like a clean, liquid rocket than a smokey, solid rocket. This lends itself to plume observation experiments, since most large Soviet intercontinental ballistic missiles are liquid fueled.

For its first orbital industrial launch vehicle (ILV), Amroc has a new design that puts together three of the 51-in.-dia. hybrid modules along with a conventional solid motor in a configuration similar to the Air Force/Martin Marietta Titan 34D launcher (artist rendering at right). This 71-ft.-tall launcher, called Slingshot or ILV-S, is aimed at use for small satellites in the Defense Advanced Research Projects Agency Lightsat program category, and can put a 600-lb. payload into a 135-naut.-mi. circular polar orbit (AW&ST Aug. 10, p. 22). Slingshot is taking priority over Amroc's earlier, larger ILV-1 design (AW&ST Sept. 29, 1986, p. 18).

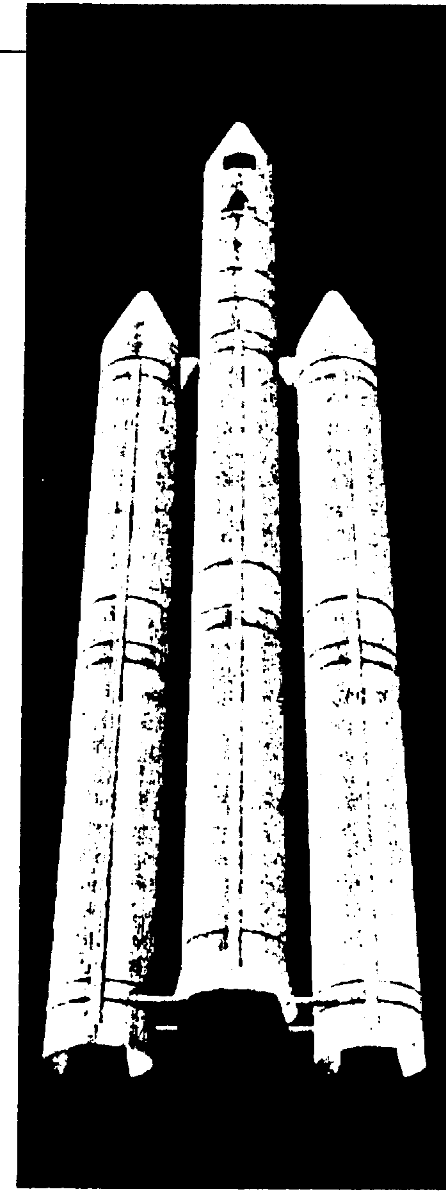
Slingshot has two strap-on, hybrid modules for the first stage, a center module for the second stage, topped by a spin-stabilized solid motor, such as the Morton Thiokol Star 48, for the third stage. The center module has about four times the expansion ratio of the strap-ons for more efficiency in the vacuum of space.

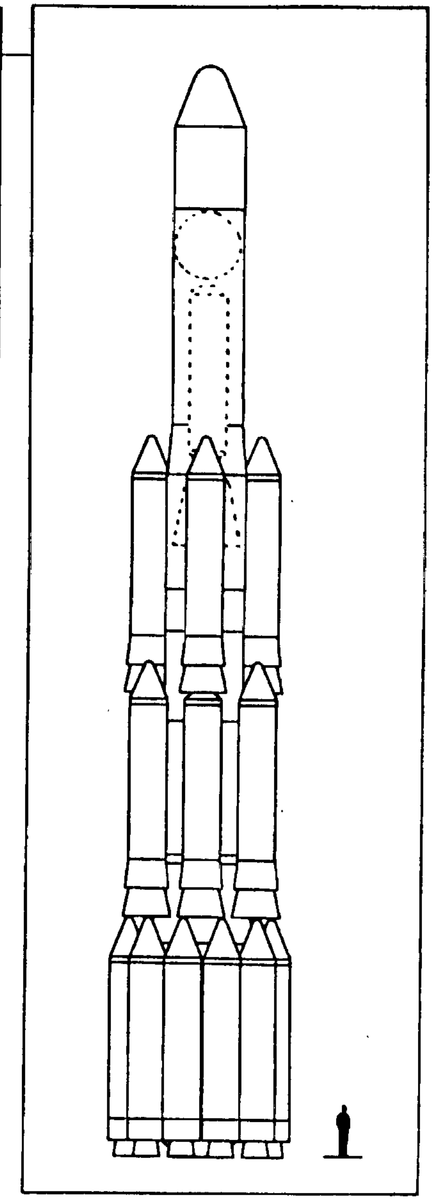
Slingshot payload capability is roughly comparable to a Vought Scout booster, which costs over $10 million per launch. Amroc estimates its launch would cost about $5 million and expects the first flight to be in early 1989.

Amroc made its first test firing of the 70,000-lb.-thrust module on Oct. 14, using a steel case for the ground test instead of a filament-wound flight case. The motor was shut off after about five sec. of full thrust after hot gas escaped from a broken igniter line and the thrust mount proved too flexible.

Flight weight of the 70,000-lb.-thrust module is estimated at 26,000 lb., twice that of the 33,000-lb.-thrust modules that Amroc previously had planned to use and already has tested. This doubling of module size largely reflects an inability to economically reach the mass fraction (propellant weight divided by total weight) assumed in previous plans.

This has resulted in a redesign of the company's larger, four-stage ILV-1 from 19 33,000-lb.-thrust modules to 22 of the 70,000-lb.-modules (shown in diagram at far right). ILV-1 payload capability remains at 3,000 lb. to a 135-naut.-mi. polar orbit.





Martin's ALS Booster Design Uses Multiple Strap-On Motors

By Bruce A. Smith

Los Angeles—The design Martin Marietta is studying for the advanced launch system (ALS) interim booster has a cryogenic propellant central core vehicle with 4-10 strap-on monolithic solid rocket motors, depending on specific mission requirements.

Martin Marietta program officials believe that the strap-on motors with one-piece cases instead of the large segmented designs used on the space shuttle and Titan booster will significantly decrease the cost of the ALS and provide flexibility because of the range of solid rocket motor thrust available.

Simplified Design

LeRoy F. Nichalson, director of advanced programs for Martin Marietta Astronautics Co., said the motors would be about 55 ft. long and 8 ft. in diameter. The pair of large solid rocket motors for the Titan 34D launcher, by comparison, are 90 ft. long, 10 ft. in diameter and produced in segments that are stacked at the launch site to form a complete motor.

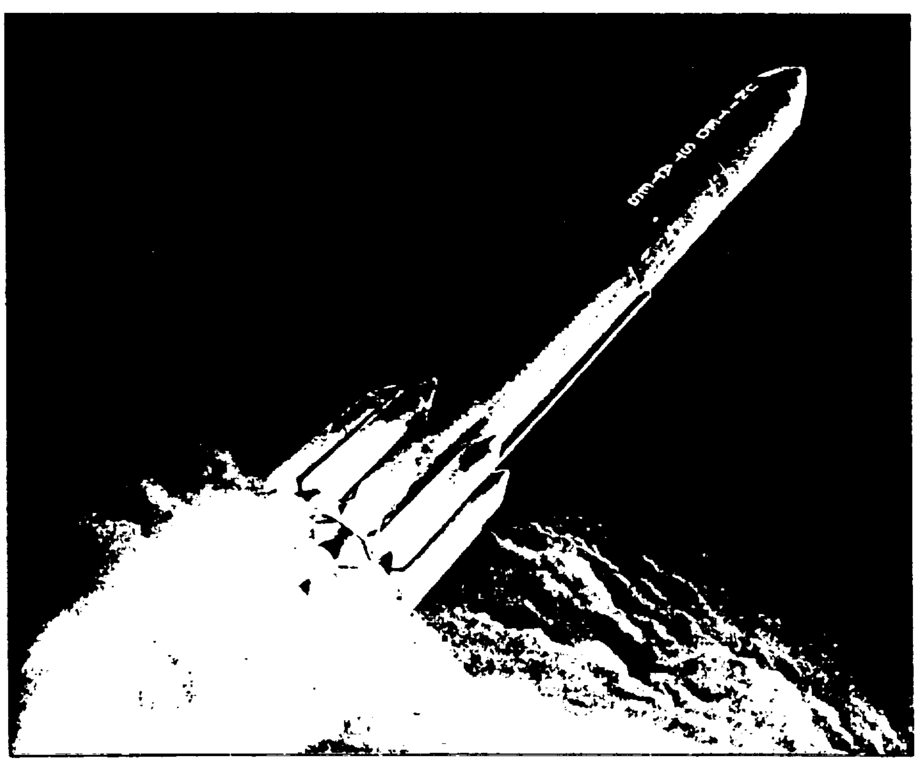
The Martin Marietta ALS motors—which could be manufactured in large production quantities with automated manufacturing systems to further reduce launch system production costs—would be transported horizontally on a rail car to a launch site essentially ready for use.

The motors also would have fixed exhaust nozzles to further simplify design and production. Steering at liftoff would be accomplished through four liquid propellant engines on the core vehicle, which would produce about 35% of the total thrust of the vehicle at launch to provide adequate steering control authority.

James W. McCown, vice president of advanced programs for Martin Marietta Astronautics Co., said the strap-on motors probably would burn for 65-70 sec. to provide thrust through the period of maximum aerodynamic pressure.

The interim ALS vehicle would be fully expendable because of the design requirements posed by the reentry environment and the time required to recover and return systems to the launch site, which could slow processing for the next launch.

Core propulsion would be a liquid oxygen/liquid hydrogen system that could use space shuttle main engines during initial ALS operations. Cost of shuttle main engines for use on the expendable interim



Martin Marietta interim design concept for the advanced launch system (ALS) includes monolithic strap-on solid rocket motors and a cryogenic-core, first-stage propulsion system. The vehicle, which could be available in the early 1990s, would be capable of placing up to 125,000 lb. of payload into low Earth orbit.

ALS could be reduced by selecting engines used on previous space shuttle missions and manufacturing less costly engines designed and built to expendable engine specifications rather than multiple missions for the shuttle program.

The core vehicle's liquid propellant engines would be ignited initially on the launch pad, similar to the space shuttle launch sequence, to ensure the engines are performing properly prior to ignition of the strap-on motors. This would enable launch officials to shut down the liquid propulsion system and abort the mission if a system problem were detected.

Seven Contractors

There are seven contractors working on one-year advanced launch system design study contracts from the Air Force, Boeing Aerospace Co., General Dynamics Space Systsems Div., Hughes Aircraft Co., McDonnell Douglas Astronautics Co., Rockwell International, USBI Booster Production Co. and Martin Marietta. The advanced launch system program is aimed at reducing launch costs by a factor of 10 with innovative concepts covering the entire launch system.

The Air Force wants to have the ALS available not later than 1998, but also would like a partial capability, or interim vehicle, available to significantly reduce launch costs by 1993-94. The interim design—which could use some existing launch vehicle systems—would be available in the event a decision were made by 1988 or 1989 to use the system for deployment of an initial strategic defense system or deploy structures for the space station.

Initial Design

Initial Martin Marietta design for the interim and the full-up ALS vehicle, called the objective vehicle, would have a common core, although there could be some changes to the objective vehicle for higher production rates.

The objective launcher could be a flyback booster with a liquid oxygen/hydrocarbon—possibly methane—propulsion system that would separate from the other section of the launch system at Mach 3 and glide back to Earth. The Mach 3 velocity was selected for staging the flyback booster because of the availability of conventional materials capable of enduring fuselage surface temperatures up to that velocity.

With a Mach-3 separation, a bare aluminum alloy skin on the glide-back booster would be able to accommodate short duration peak temperatures below 300 deg. The return vehicle could have turbine engines for a go-around capability, but the Martin Marietta baseline design currently does not include turbine engines.

A new launch facility would be developed for the interim and objective boosters, with final assembly and checkout of the ALS at the launch site using a minimum number of ground crew personnel. The assembly and checkout facility probably would be located near Vandenberg AFB, Calif., since Vandenberg will be a major launch site for the system.

In addition to the glide-back booster, Martin is looking at an expendable objective system similar to the interim vehicle. The company is studying tradeoffs of projected launch rates versus the added cost of making a launcher partially reusable—since a reusable system would have greater potential payoff at higher launch rates.

Martin Marietta favors a simple, less costly, expendable vehicle, but is continuing to look at both options. "We think it's the most important trade," McCown said.

Another key issue is the tradeoff between cost and launcher reliability. McCown said the additional cost to increase the booster's success rate may be worth the investment when viewed in terms of systemwide cost resulting from a launch failure—including the cost of lost payloads and those associated with temporary halting of launch operations. He added that the cost of the actual launch vehicle is only about 20-25% of the total space system cost, including the payload.

Rocket engines are the area of greatest potential savings for launch vehicles, McCown said, adding that investments should be made to tool for the production of rocket engines in the same manner that jet turbine engines are manufactured for aircraft. McCown believes investing in decreased production costs for rocket engines is preferable to investing in vehicle complexity for reusability.

Other significant vehicle savings are possible by application of the latest computer automation technology to launch systems. There are significant gains to be made in this area, McCown said, since, until recently, expendable launch vehicles were being phased out and it was not feasible for manufacturers to consider modernizing the vehicles with the latest technology in automation. □

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6.8.1 BOEING

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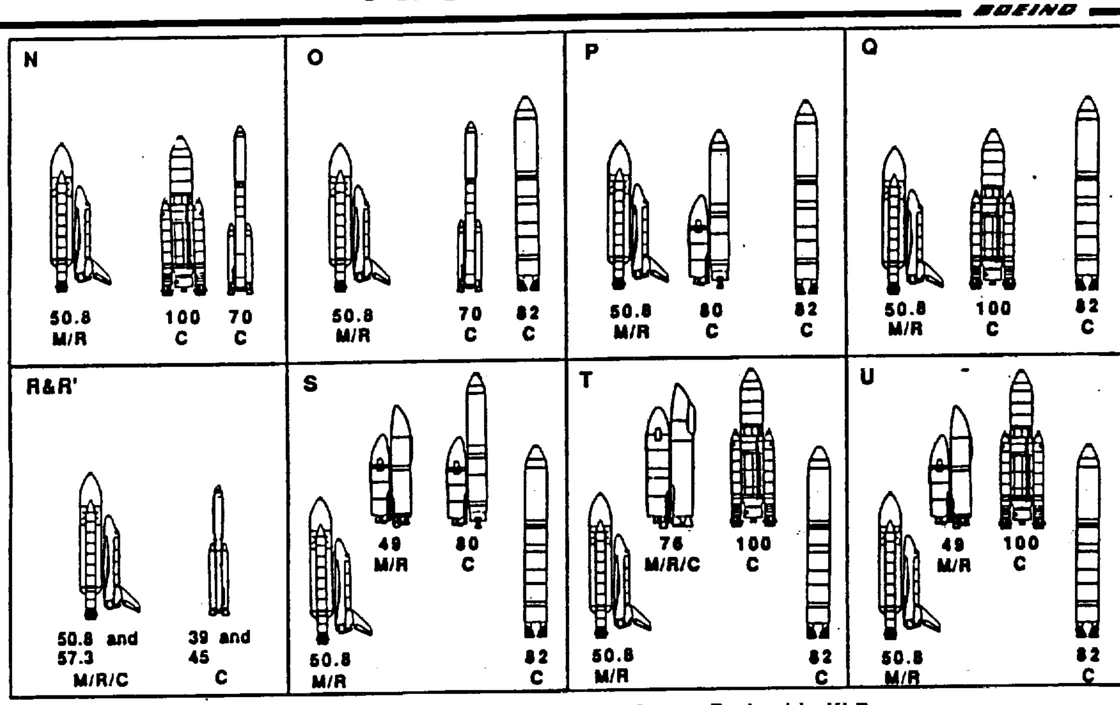
Major Vehicles of Architectures

BOEING



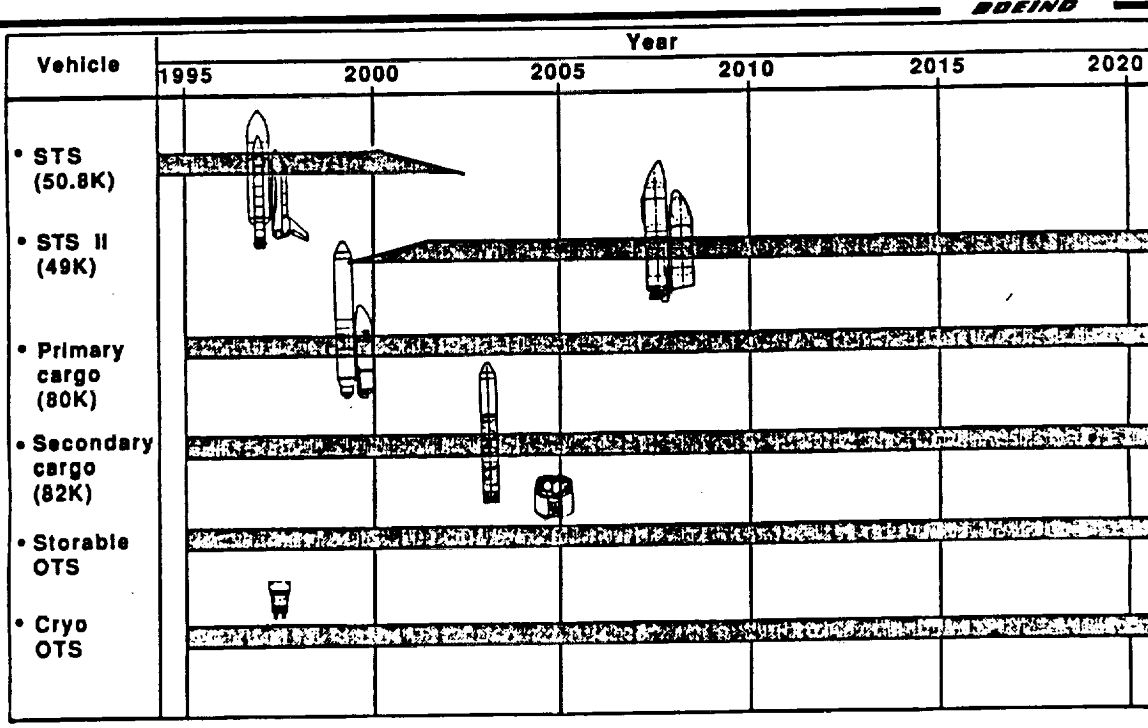
M = Man R = Return C = Cargo Numbers = Payload in KLB

19

3-4-2574

Recommended Architecture Overview

BOEING



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Recommended Architecture New Launch Vehicles

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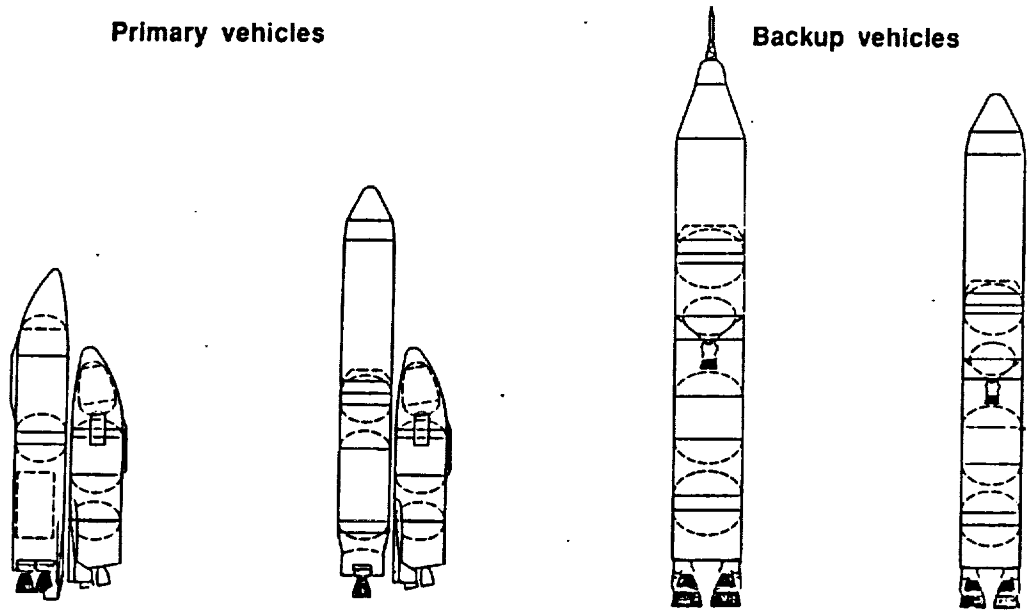
BOEING

Primary vehicles | Backup vehicles



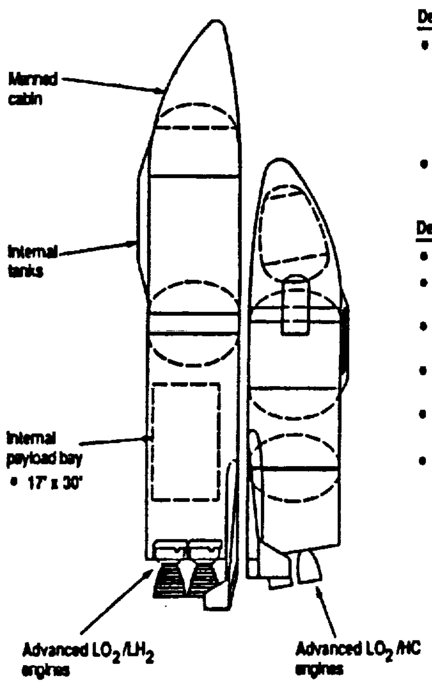
Manned	Cargo	Manned	Cargo
RFLY-ROI	RFLY-PPA	ECON-ECON	ECON-ECON
Payload = 48,900	Payload = 80,050	with CERV	Payload = 81,600

135

Recommended Architecture Primary Manned/Return Vehicle

3-6-2723

BOEING

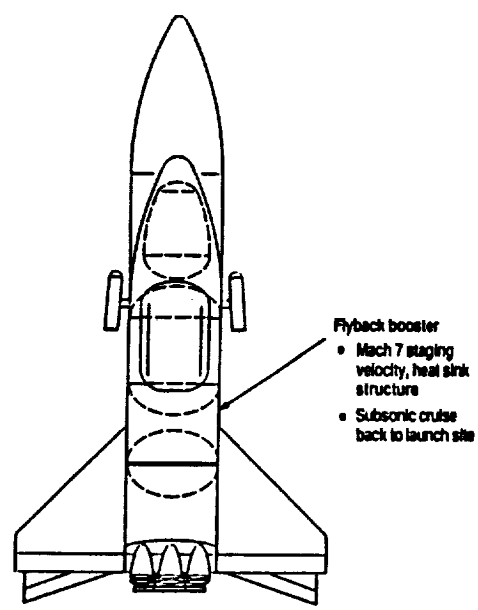


Design approach

- Minimize cost/flight
  - Fully reusable
  - Optimum size
  - Reduced ground and flight operations cost
- Maximize system reliability

Design features

- 2000 IOC
- High performance and design margins
- Full engine out capability - both stages
- High degree of redundancy and fault tolerance
- Extensive autonomy and built-in test
- Common booster with RFLY-PPA

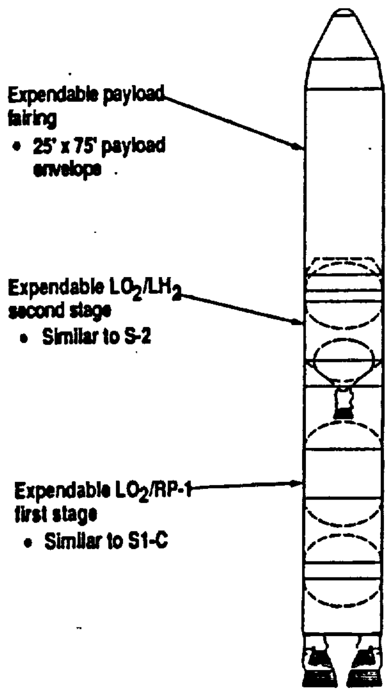


GLOW	2,020,000
Payload	48,900

47

Recommended Architecture Secondary Cargo Vehicle

BOEING



Design approach
- Lowest DDT&E cost
  - Existing propulsion
  - Low risk proven design
  - Fully expendable
- Improved cost/pound, reliability compared to current ELVs

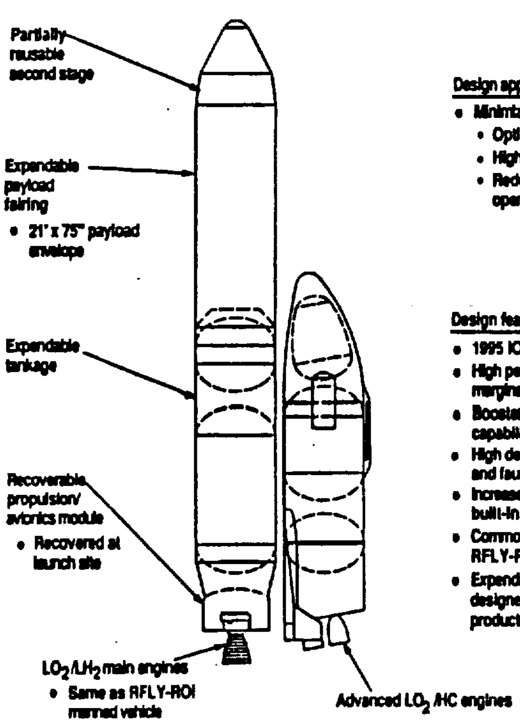
Design features
- 1995 IOC - minimal risk
- Saturn V main engines, configuration concept
- Current state-of-the-art lightweight structures
- Fault-tolerant avionics with increasesd built-in test
- Payload fairing and stage airframes designed for automated production

GLOW 2,348,800
Payload 81,600

49

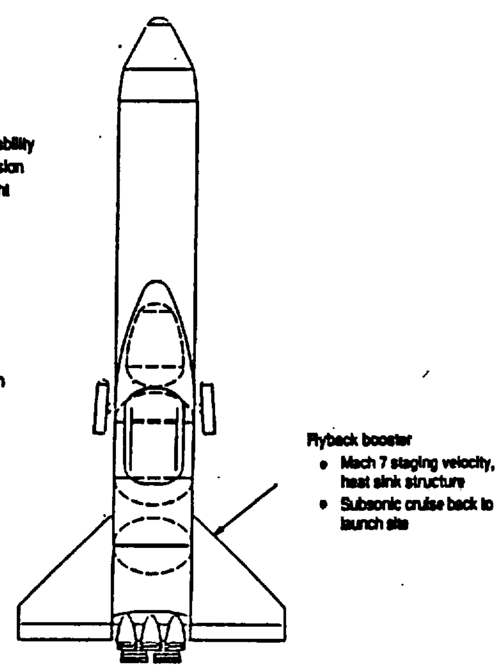
Recommended Architecture Primary Cargo Vehicle

BOEING



Design approach
- Minimize cost/pound
  - Optimum degree of reusability
  - High performance propulsion
  - Reduced ground and flight operations costs

Design features
- 1995 IOC
- High performance and design margins
- Booster full engine out capability
- High degree of redundancy and fault tolerance
- Increased autonomy built-in test
- Common booster with RFLY-ROI
- Expendable hardware designed for automated production

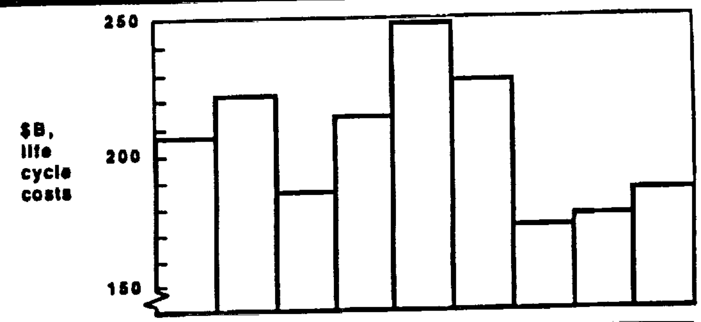


GLOW 2,020,000
Payload 80,050

45

Candidate Architectures
Life Cycle Costs

BOEING



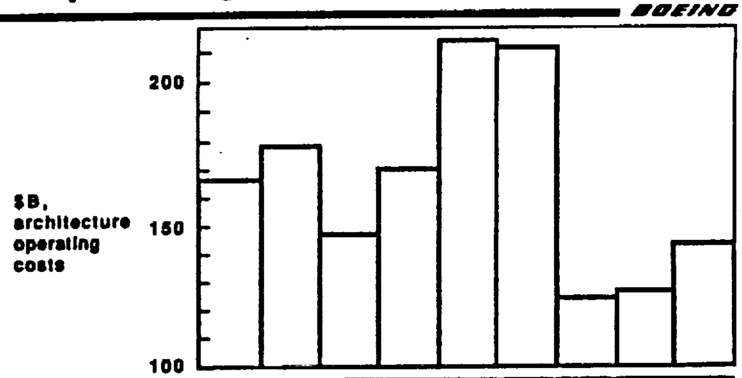
Systems \ Architectures	N	O	P	Q	R	R'	S	T	U
STS to 2020	✓	✓	✓	✓	✓	✓			
STS, phased out by 2003							✓	✓	✓
STS II, small, from 2000							✓		✓
STS II, large cargo, from 2000								✓	
Manned assured access capsule	✓	✓	✓	✓			✓	✓	✓
Cargo, partially reusable, flyback booser			✓				✓		
Cargo, partially reusable, solid booster	✓			✓				✓	✓
Cargo, expendable, all liquid		✓	✓	✓			✓	✓	✓
Cargo, expendable, solid boost, liquid core	✓	✓							
Two independent expendable OTS	✓	✓	✓	✓			✓	✓	✓
Titan IV					✓	✓			
Current upper stages					✓	✓			

29

3-5-2707

Candidate Architectures
Operating Costs

BOEING



Systems \ Architectures	N	O	P	Q	R	R'	S	T	U
STS to 2020	✓	✓	✓	✓	✓	✓			
STS, phased out by 2003							✓	✓	✓
STS II, small, from 2000							✓		✓
STS II, large cargo, from 2000								✓	
Manned assured access capsule	✓	✓	✓	✓			✓	✓	✓
Cargo, partially reusable, flyback booser			✓				✓		
Cargo, partially reusable, solid booster	✓			✓				✓	✓
Cargo, expendable, all liquid		✓	✓	✓			✓	✓	✓
Cargo, expendable, solid boost, liquid core	✓	✓							
Two independent expendable OTS	✓	✓	✓	✓			✓	✓	✓
Titan IV					✓	✓			
Current upper stages					✓	✓			

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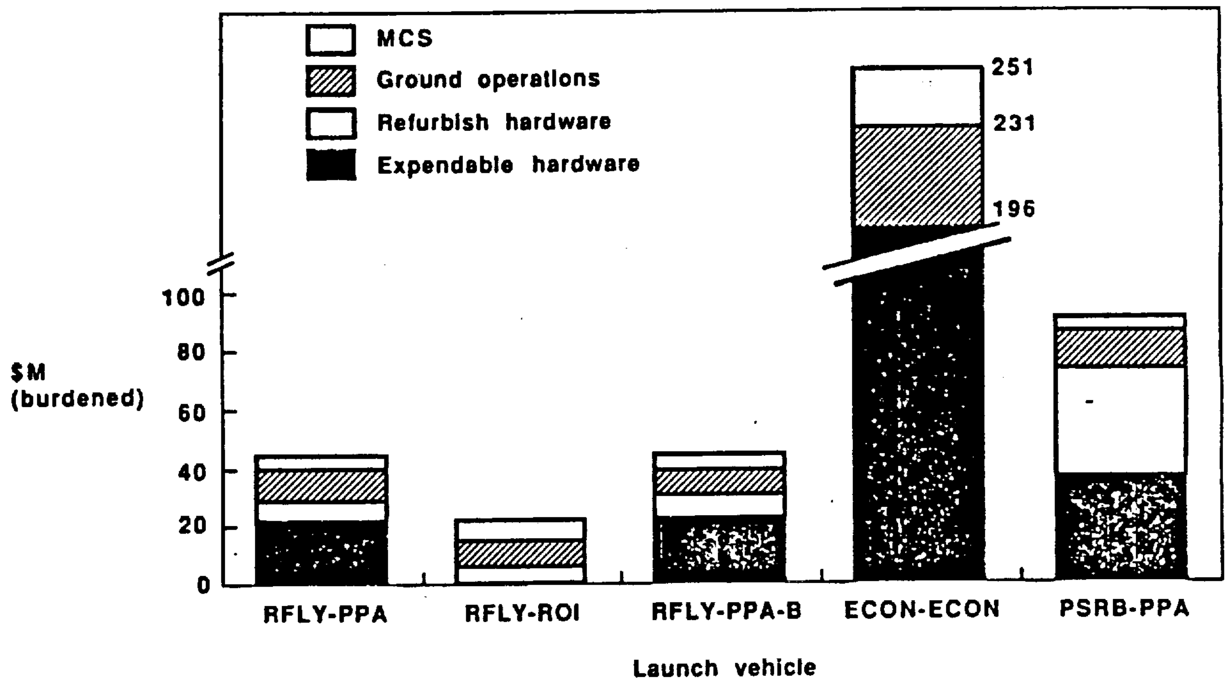
Launch Vehicle Cost Per Flight

BOEING



Launch Vehicle Costing
Groundrules and Assumptions

BOEING

- Constant 1986 dollars
- Costs include 39% program burden (except for govt furnished costs)
- DDT&E includes 3 flight tests over one year for partially/fully reusable vehicles and two flight tests over six months for expendable vehicles
- Refurbishment hardware for winged vehicles is priced at 1/2% of the TFU
- Refurbishment hardware for the recovery modules is priced at 2% of the TFU
- 85% learning curve used for expendable hardware
- 90% learning curve used for reusable hardware
- Achitecture S assumes that the manned orbiter (ROI) and recovery module (PPA) have common engines as well as sharing a common fly back booster (RFLY). The development costs for the engines and RFLY are included with the RFLY-PRA.

All costs are represented in constant 1986 dollars and include the 39% wraparound factor for Program/Government support, profit and management reserve (except for government provided costs). The standard test program factor set outlined in the STAS groundrules update has been incorporated in our costing philosophy. Our vehicle development costs include 3 equivalent sets of hardware for fully and partially reusable vehicles and 2 equivalent sets for expendable vehicles. The costs for 3 flight tests for reusable vehicles over 1 year and 2 flight tests for expendable vehicles over 6 months have been accounted for in the vehicle development costs. 50% of the Theoretical First Unit (TFU) has also been added to vehicle development for refurbishment of the flight test vehicle. To account for the cost associated with hardware component replacement due to normal wearout, we've added 1/2% of the TFU for the winged vehicles (RFLY and ROI) and 2% of the TFU for the recovery module. In our production costs we've assumed that the expendable hardware elements such as the core tanks and fairing that go with the recovery module, follow an 85% learning curve and reusable hardware such as the RFLY and recovery module follow a 90% learning curve. Following an 85% learning curve means if the first unit costs $100M, the second will cost 85% of it or $85M, and the forth will be 85% of the second or $72.25, and so on. With a break in production of more than a year for any of the vehicles, the next unit produced is assumed to be equivalent to the TFU, thus subsequent units are costed as if they were the second, third, etc.

New Technology Prioritization
Recommend Architeture

BOEING

	Delta LC benefit (M$)	Delta PV ($M)	IRR (%)
• Enabling technologies			
1. Advanced LOX/HC engine 2. Reusable LH_2 tankage and insulation 3. Actuator system for CCV 4. Maneuvering terminal decelerators	28700	10819	Always positive return
• Enhancing technologies			
1. Built-in test	2617	911	140
2. Automated data management system	1898	709	115
3. Low cost expendable cryogenic tanks (AL-LI application)	2055	779	104
4. Multibody ascent CFD	88	58	89
5. Automated test and inspection	1454	498	61
6. Lightweight materials for primary structure (graphite composite fairing)	929	332	34
7. Accelerated loads cycle	247	48	19.5
8. Advanced TPS	218	59	16
9. Advanced fault-tolerant computers	106	30	15.5
10. Automated transfer and handling	830	227	15
11. Centralized, secure data base management system	5413	1427	13.5
12. Computer aided software development	2225	552	12.5
13. Expert systems (for flight planning, payload integration, etc.)	5775	1374	11.5
14. Advanced maneuvering propulsion	46	18	11.5
15. Autonomy and adaptive GN&C	716	43	6
Enhancing total	24617	7417	

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3-4-2754

Launch Facilities

BOEING

Facility	WTR		ETR	
	Number of units	Facility capability (flights/year)	Number of units	Facility capability (flights/year)
Launch pad	3	52	4	72
Center core processing facility	2	26	1	13
Tank processing facility (ECON-ECON)	1	12	1	12
Large payload integration facility cell	2	36	1	18
Payload integration facility (RFLY-ROI) cell	1	16	3	48
Stacking and integration cell	2	30	4	60
Booster processing facility	2	50	3	75
Orbiter processing facility	1	15	3	45
P/A module recovery facility	1	260	1	260
Booster/orbiter recovery facility	1	130	1	130
Firing room (launch processing system)	5	48	8	75
Mobile launcher platform	3	36	5	60
Crawler transporter	2	66	2	66
OTS Processing facility	2	24	2	24

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Conclusions

BOEING

- Existing systems:
  - Cannot perform the most critical 15% of the mission model
  - Are the highest cost approach
  - Do not provide assured access
  - Require very extensive facilities
- Recommended architecture features:
  - STS phased out by 2003
  - Fully reusable, small (49K), STS II
  - Primary cargo vehicle is partially reusable with flyback booster (80K)
  - STS II and primary cargo vehicle share flyback booster
  - Secondary cargo vehicle (82K)
  - Manned assured access capsule (launched by cargo vehicle)
  - One cryogenic and one storable orbit transfer system
  - Assured access mission control systems
- Recommended architecture benefits:
  - Meets all mission requirements including assured access
  - Vehicles have high reliability features
  - Highly flexible; readily extendible to, e.g., SDI deployment
  - Highest score on resiliency, operational availability, environmental acceptability, etc.
  - Lowest cost

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3-4-2731

Recommendations

BOEING

- Introduce flyback booster cargo vehicle by at least 1995
  - Early introduction benefits:
    - Early cost payback
    - Avoids STS build-up
- Replace STS with fully reusable two-stage STS II
  - Keep cost down by using cargo vehicle flyback booster (backed up for assured access)
- Begin supporting technology program

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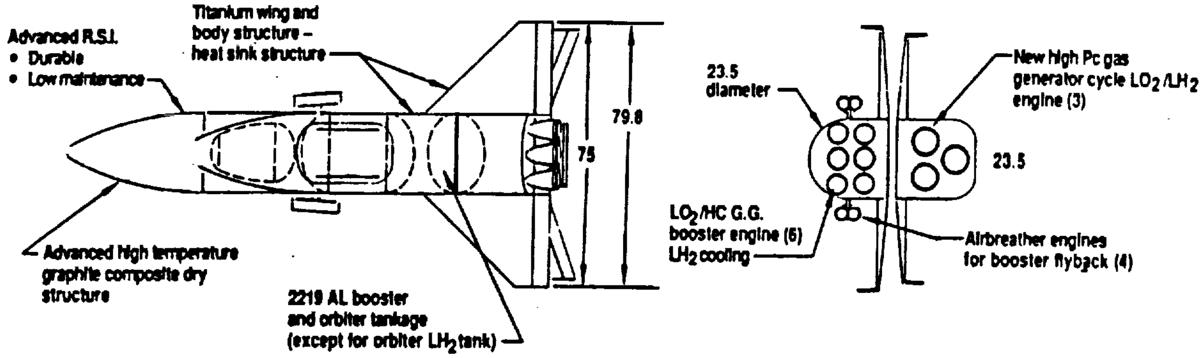
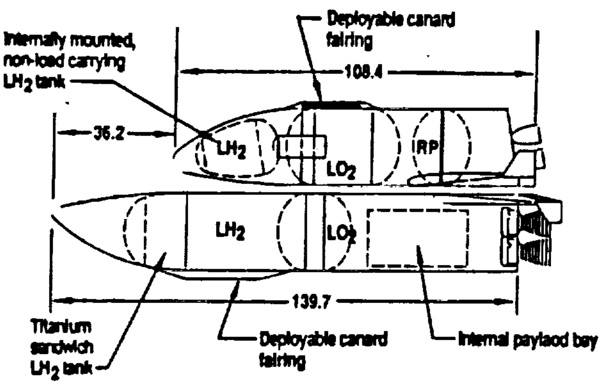
3-6-2724

RFLY-ROI Configuration

BOEING





Characteristic	RFLY booster	ROI Orbiter
Gross lift-off weight Payload weight	2,020,000 49,000	
Total stage weight Usable propellant Inert weight Ideal velocity delta	1,272,730 1,068,565 204,165 11,404	698,349 581,279 117,070 18,737
Total ideal velocity	30,141	
Number of engines Type/propellants Rated thrust ISP Mixture ratio Chamber pressure Weight	6 G.G. - LO2/HC 426.5K/483.3K 358.55 3.35 4000 4200	3 G.G. - LO2/LH2 161.4K/273.3K 467 6 4500

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RFLY-ROI CONFIGURATION

The RFLY-ROI is a manned/return vehicle system featuring a reusable flyback booster and a reusable winged orbiter. The booster and core engines run in parallel during the boost phase. With a gross lift-off weight of 2,020,000 lbs, this system is capable of placing 49,000 lbs in a 150 nautical mile circular orbit.

The RFLY booster is the same booster as that used for the recommended RFLY-PPA system; refer there for more details.

The ROI is designed to carry a two-man crew in a cabin located in the nose of the vehicle. Accommodations for larger crew sizes, if necessary, are achievable via kits located in the payload bay.

The propulsion system for the ROI consists of three new, high chamber pressure, gas generater cycle LO2/LH2 engines incorporating a variable expansion ratio nozzle. These are the same engines described for the PPA core vehicle on the recommended RFLY-PPA.

The ROI orbiter features an aluminum-lithium LO2 tank and for structural and thermal control reasons, a titanium sandwich - constructed LH2 tank. Advanced high temperature graphite composite materials will comprise the majority of the ROI body structure and wings. The potential strength and weight properties of composites make them an attractive option for a 2000 timeframe vehicle based on performance and cost considerations.

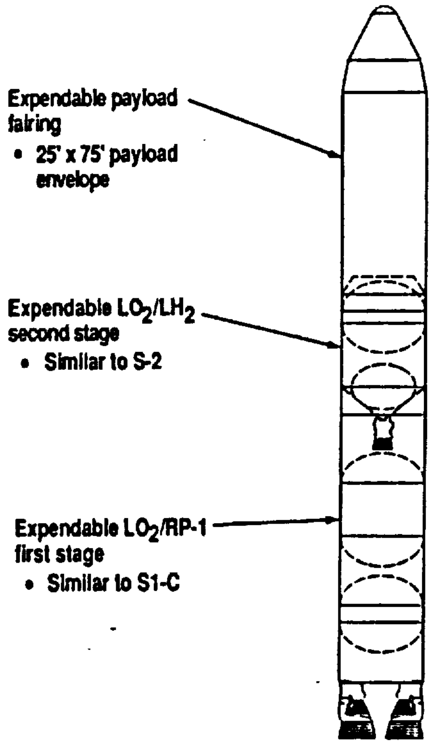
Thermal protection for the orbiter is accomplished with advanced reusable surface insulation. Durable, low maintenance ceramic tiles will protect the high temperature windward surfaces. Flexible insulation blanket will be used for the lower heating areas.

Like the RFLY booster, high fault tolerance and increased redundancy are the key features of the ROI avionics subsystem.

Aerodynamically, the orbiter is configured in much the same fashion as the RFLY; like the RFLY, it's designed as a control configured vehicle. A forward deployable canard is provided for trim control for the subsonic portion of flight. In addition to the canard, wing tiplets and aerodynamic control surfaces help to minimize the size of the wings.

ECON-ECON Cargo Vehicle

BOEING



Design approach
- Lowest DDT&E cost
  - Existing propulsion
  - Low risk proven design
  - Fully expendable
- Improved cost/pound, reliability compared to current ELVs

Design features
- 1995 IOC - minimal risk
- Saturn V main engines, configuration concept
- Current state-of-the-art lightweight structures
- Fault-tolerant avionics with increasesd built-in test
- Payload fairing and stage airframes designed for automated production

GLOW 2,348,800
Payload 81,600

145

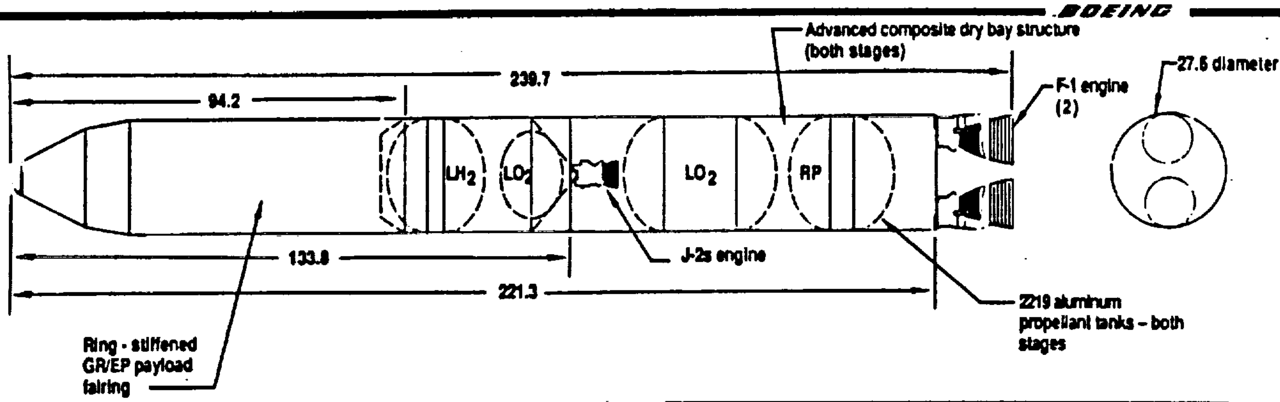
ECON-ECON CARGO VEHICLE

The ECON-ECON vehicle is a conventionally designed fully expendable launch vehicle using the existing Saturn V first and second stage engines. Achieving a minimal front-end (DDT&E) cost is the foremost design objective for this vehicle concept. This goal is to be accomplished by using existing propulsion elements, and implementing a low technical risk, fully expendable proven design approach.

Another design goal for this vehicle is to improve its cost per pound and reliability values compared to current expendable launch vehicles. The means for attaining this goal are to be found in the use of fault tolerant avionics with increased built-in test capability, and by employing a conventional state of the art lightweight airframe design. To aid in the reduction of manufacturing (recurring) costs, the payload fairing and first and second stage airframes are designed to accommodate automated production processes. The goals and design feature described for this vehicle present a low risk option for a 1995 IOC date.

ECON-ECON Configuration

3-6-2726



Characteristic	First stage	Second stage
Gross lift-off weight	2,348,820	
Payload weight	81,600	
Total stage weight	1,925,370	319,632
Usable propellant	1,781,066	281,527
Inert weight	144,304	38,105
Ideal velocity delta	9358	21,431
Total ideal velocity	30,789	
Number of engines	2	1
Type/propellants	F-1 - LO_2 /RP-1	J-2S - LO_2 /LH_2
Rated thrust	1522K/1748K	/265K
ISP	304	436
Mixture ratio	2.27	5.5
Chamber pressure	982	NA
Weight	18,620	3800

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ECON-ECON CONFIGURATION

The ECON-ECON vehicle is a conventionally designed fully expendable cargo vehicle with first and second stage designs similar to Saturn S1-C and S-2 designs, respectively. With a gross light-off weight of 2,348,820 pounds, this vehicle is capable of placing about 81,600 lbs into low earth orbit. As implied from its inline configuration, this is a series burn vehicle.

The first stage propulsion system is comprised of two LO2/RP-1 burning F-1 engines. This is an existing engine as originally used on the Saturn V. The two F-2 engines produce a total sea level thrust of 3,044,000 lbs. At lift-off this results in a thrust/weight ratio of 1.296. The second stage is powered by a single J-2S LO2/LH2 engine, which is an upgrade of the existing J-2 engine. This engine is capable of delivering 265,000 lbs. of vacuum thrust.

All the propellant tanks are constructed of 2219 aluminum; automated production methods are expected to minimize their manufacturing costs. Structurally, advanced composites have been selected for the drybays, and a ring-stiffened graphite/epoxy composite for this payload fairing; this represents a lightweight approach and the technology associated with it presents no major problems for the anticipated IOC date. The fairing on this concept provides for a 25 ft x 75 ft payload envelope.

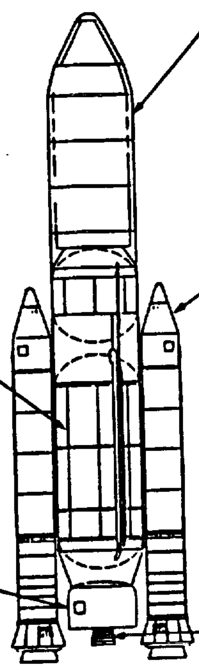
Shuttle external tank spray-on foam insulation (SOFI) is used over the second stage LH2 tankage. In addition, ablative-type insulation is employed in locally "hot" regions. The first stage does not require an insulation beyond a base heat shield necessary to protect against plume heating effects.

3-6-2727

PSRB-PPA Cargo Vehicle

BOEING

GLOW 3,361,550
Payload 102,500



Design approach
- Low DDT&E cost
  - Modifications of existing propulsion systems
  - Low risk design
- Low cost/pound
  - High performance core stage propulsion
  - Recoverable boosters, high value core stage hardware

Design Features
- 1995 IOC - low risk
- Fault tolerant avionics system with increased built-in test
- Expendable hardware designed for low cost automated production

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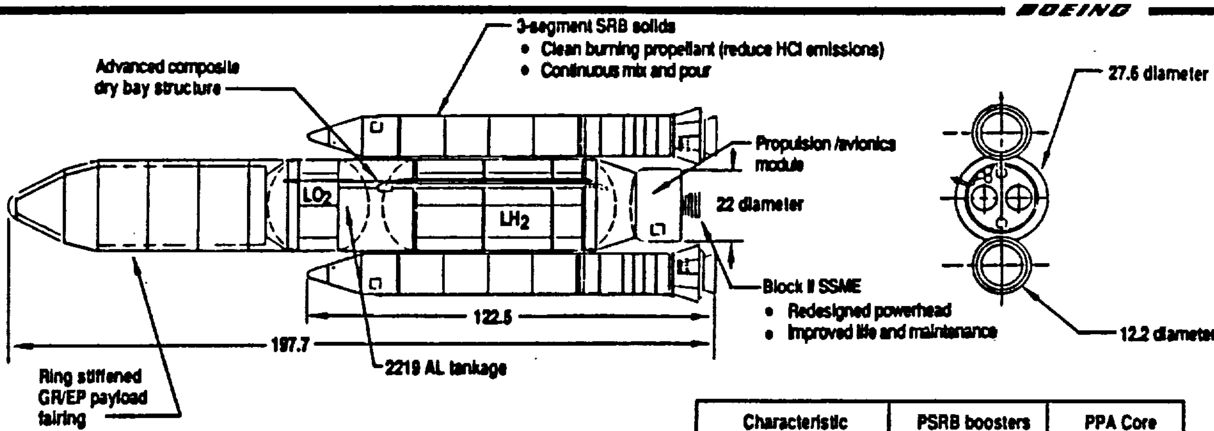
PSRB-PPA CARGO VEHICLE

The PSRB-PPA is a partially reusable cargo vehicle with Solid Rocket Boosters, expendable core tankage, and a reusable Propulsion/Avionics module (P/A module). This vehicle is cost competitive because of its low development cost, moderate recurring costs due to the recovery and reuse of high cost components, and use of a new fault tolerant avionics system which contributes to a high mission success and recovery reliability.

Low Design and Development (DDT&E) costs result from the use of modified existing propulsion elements and the vehicle's relatively low risk design. These features also enable a 1995 IOC date.

Recovery of the engines and avionics, both high cost leverage items on the core stage, is the function of the P/A module. The P/A module, along with the recovery of the solid rocket booster casings, will help to lower the cost-per-pound for this vehicle.

PSRB-PPA Configuration



Characteristic	PSRB boosters	PPA Core
Gross lift-off weight Payload weight	3,361,549 102,500	
Total stage weight Usable propellant Inert weight Ideal velocity delta	2,002,346 1,686,704 315,642 8229	1,230,694 1,117,719 112,975 23,022
Total ideal velocity	31,251	
Number of engines Type/propellants Rated thrust ISP Mixture ratio Chamber pressure Weight	2 3-seg SRB solids Ave vac-1.713 x 10^6 267 NA NA See above	2 Block II SSME /470K 452.6 6 3000 7000

153

PSRB-PPA CONFIGURATION

The PSRB-PPA is a partially reusable cargo vehicle with two solid rocket booster, expendable core tankage, and a reusable Propulsion/Avionics (P/A) module. The P/A module, core tankage, and payload fairing are all configured inline for high performance and easy integration. With a gross lift-off weight of 3,361,54916, the vehicle is capable of transporting102,500 lbs of payload to a 150 nautical mile circular orbit. Both the SRB's and the core stage fire their engines during the parallel burn boost phase.

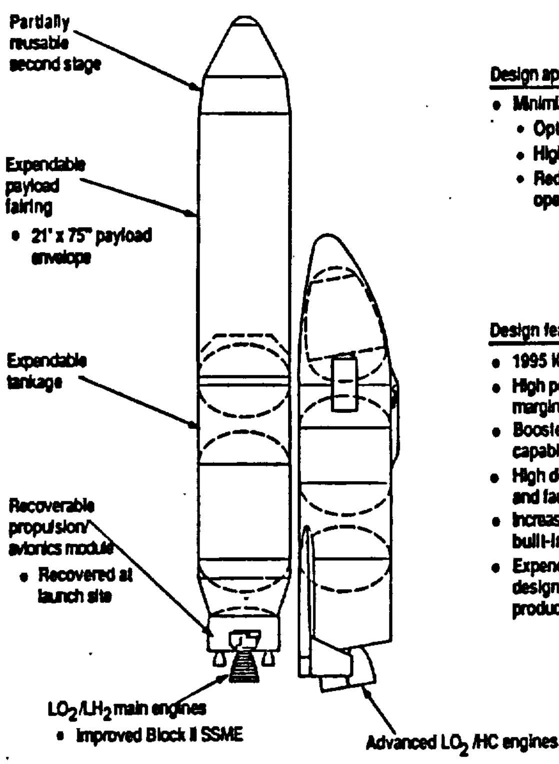
The solid rocket boosters used are a version of the STS solid booster; payload requirements dictated the use of a three-segment solid instead of the existing four-segment Shuttle solid. In addition, the solid rocket motor selected have departed from the STS SRM configuration by incorporating features to reduce manufacturing cost and to reduce HCl contaminants in the exhaust products. Cost savings are realized by utilizing a continuous mixing and pouring process. This feature substantially reduces the time and labor involved in propellant loading and the ground operations associated with segment stacking.

The main engine chosen for the core vehicle is a redesigned block II independent version of the SSME. This engine incorporates a completely redesigned powerhead to provide improved life and maintenance. This engine maintains the same physical and functional interfaces as the SSME and has essentially the same performance.

Both the core propellant tanks are constructed of 2219 aluminum; automated production methods are expected to minimize their manufacturing cost. Structurally, advanced composites have been selected for the drybay regions, and a ring-stiffened graphite/epoxy composite for the payload fairing. The fairing provides for a 25 ft by 75 ft payload envelope.

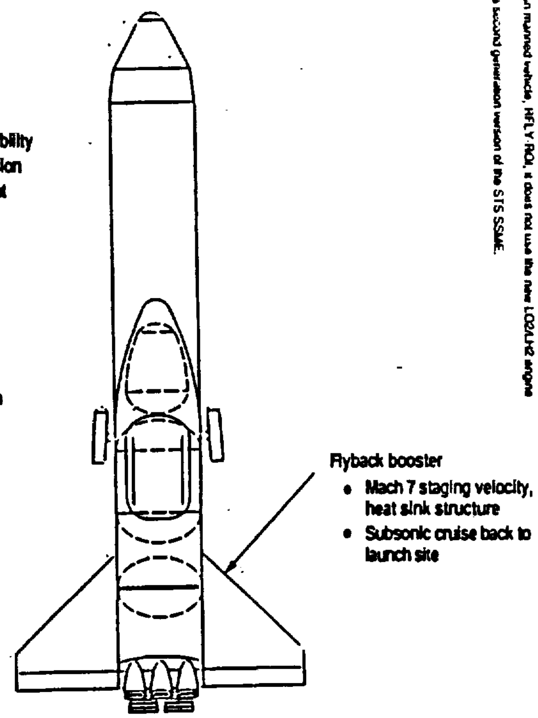
Alternate Architecture
RFLY-PPA Cargo Vehicle

BOEING



Design approach
- Minimize cost/pound
  - Optimum degree of reusability
  - High performance propulsion
  - Reduced ground and flight operations costs

Design features
- 1995 IOC
- High performance and design margins
- Booster full engine out capability
- High degree of redundancy and fault tolerance
- Increased autonomy built-in test
- Expendable hardware designed for automated production



GLOW	2,127,500
Payload	80,900

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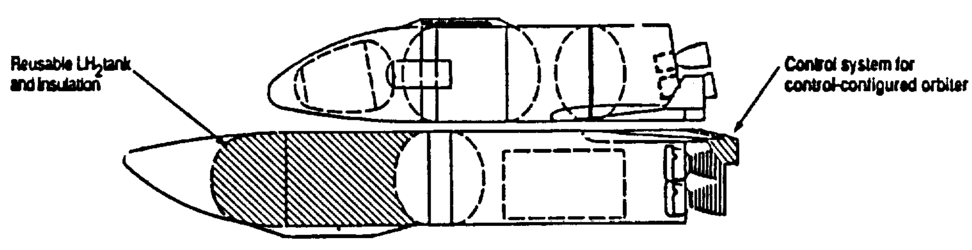
RFLY PPA - ALTERNATE ARCHITECTURE

Except for a difference in size and core propulsion, the alternate RFLY-PPA is the same as the recommended RFLY PPA described earlier; as such, it exhibits similar design approaches and features as those previously mentioned. Minimizing the cost per pound of payload is still the dominant objective. Because it does not operate in conjunction with the second generation manned vehicle, RFLY-ROI, it does not use the new LO2/LH2 engine required for RFLY ROI. Instead it uses a second generation version of the STS SSME.

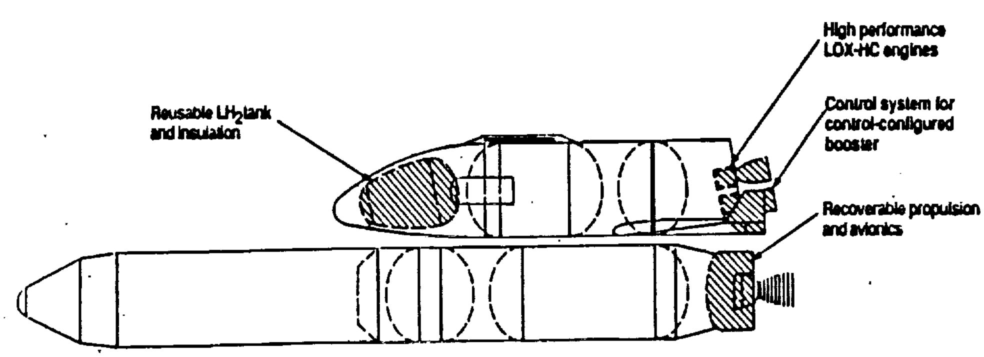
3-6-2676

Recommended Architecture
Enabling Technologies

BOEING



2000 Manned Orbiter



1995 Cargo Vehicle

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6.8.2 GENERAL DYNAMICS

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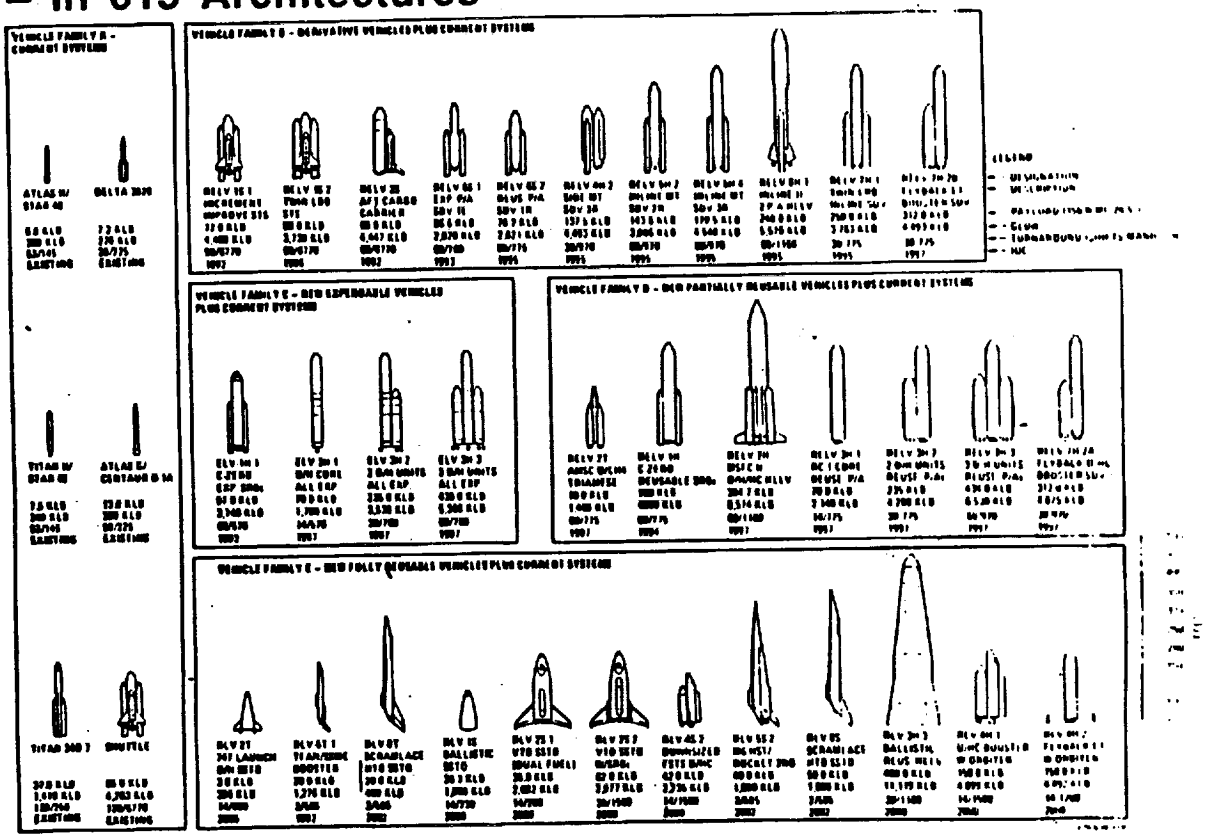
GENERAL DYNAMICS
Space Systems Division

VEHICLE FAMILIES INITIALLY ANALYZED – In 615 Architectures



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GENERAL DYNAMICS
Space Systems Division

CANDIDATE LAUNCH VEHICLES

VEHICLE TYPE	ARCHITECTURE	P/L CAPABILITIES TO 28.5 X 150/150 N MI		
		VEHICLE ID	P/L WT, K LB	P/L ENVELOPE, FT
1. SHUTTLE II, TWO STAGE	F-3, F-13, F-17	RLV-5S-2 RLV-5S-1 RLV-6S-1 RLV-5S-3	30 K/30 K 65 K/65 K 65 K/65 K 45 K/45 K	15D X 45L 15D X 65L 15D X 85L 15D X 60L
2. SHUTTLE II, SINGLE STAGE	F-6	RLV-2S-3 RLV-2S-4 (VMRE)	30 K/30 K 30 K/30 K	15D X 45L 15D X 45L
3. HYPERSONIC AIRBREATHER	F-15	RLV-8S-2	40 K/40 K	15D X 60L
4. SDV W/PAM	F-3, F-6, F-15	RELV-6S-3 RELV-5H-5 RELV-5H-6	65 K/0 139 K/0 163 K/0	15D X 60L 25D X 90L 25D X 90L
5. EXP. CORE, FLYBACK BOOSTER	F-13	RELV-12H-3(1),(4) RELV-12H-2(1),(4) RELV-12H-1(6) RELV-12H-1(2),(8) RELV-7H-8(4),-9(3)	97 K/0 130 K/0 150 K/0 193 K/0 155 K/0	15D X 60L 25D X 60L 25D X 80L 25D X 80L 25D X 80L
6. NEW ELV, SRMs	F-17	ELV-12H-1(1) ELV-12H-4(1) ELV-12H-2(1),(4) ELV-15H-1(2)	97 K/0 94 K/0 115 K/0 149 K/0	15D X 60L 15D X 60L 25D X 60L 25D X 60L
7. UNMANNED P/L RETURN	TBD	RELV-18S-1	40 K/40 K	15D X 45L
8. MANNED GLIDER	TBD	RELV-18S-1	10 K/10K	12D X 20L

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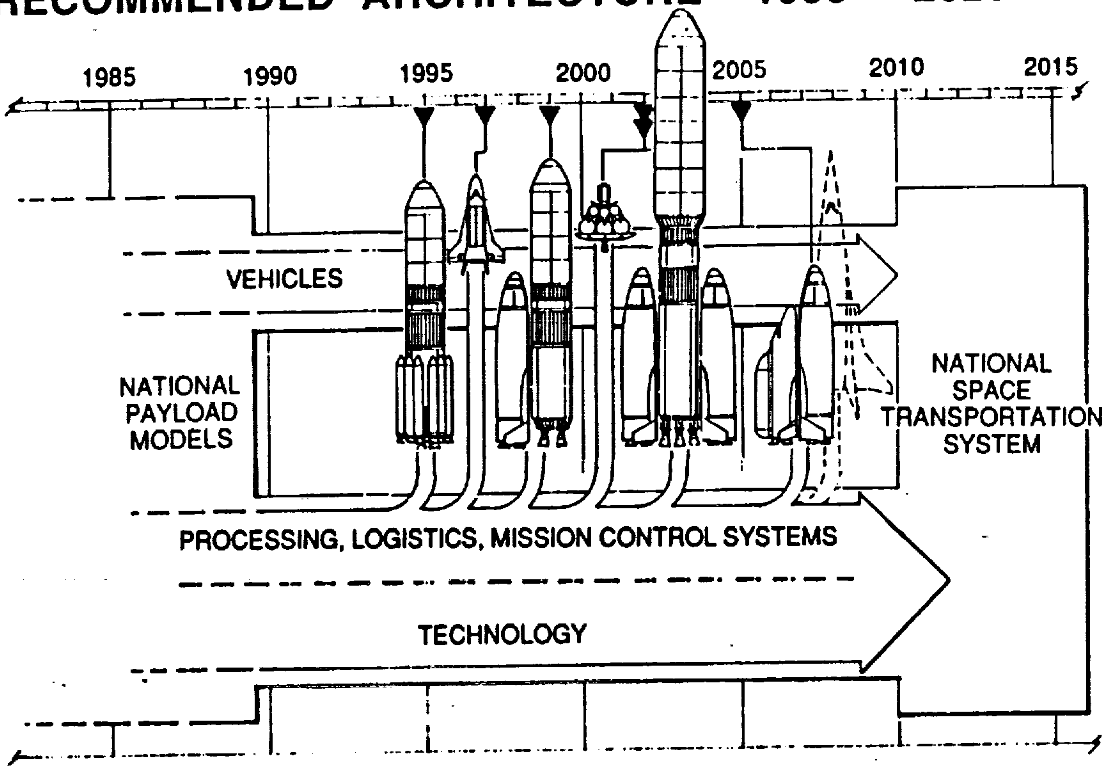
RECOMMENDED ARCHITECTURE 1995 - 2020



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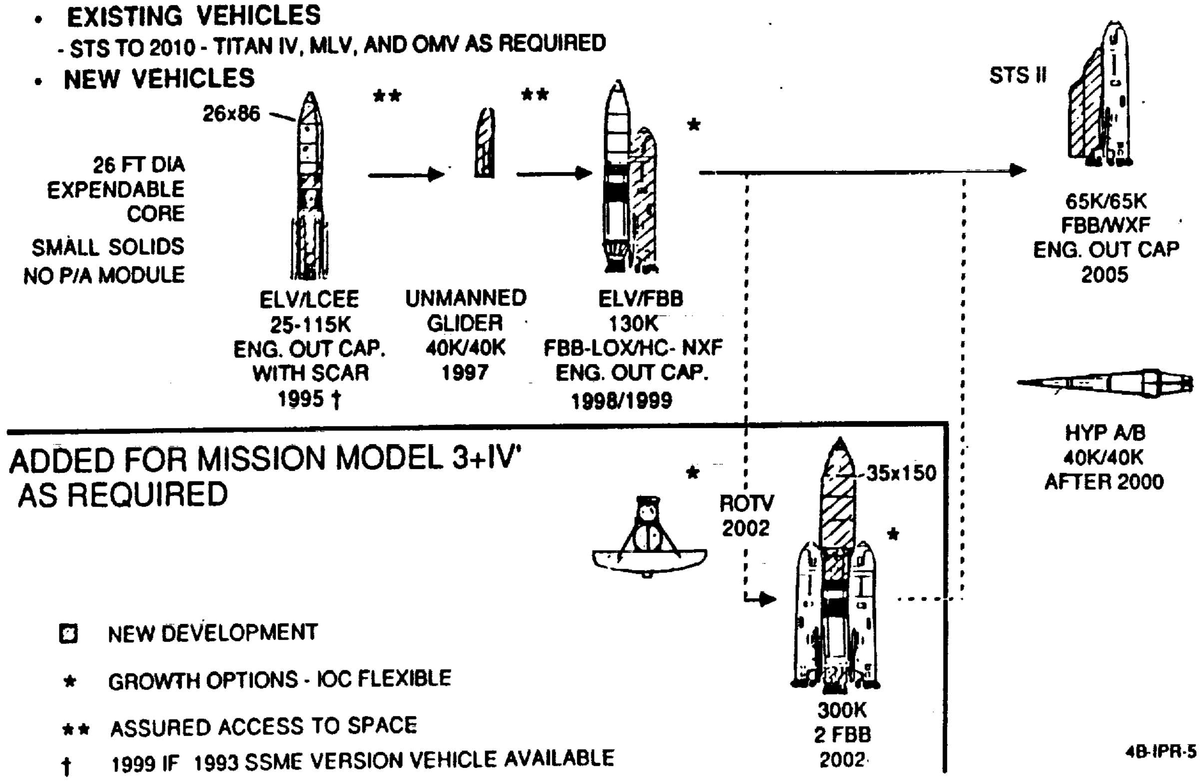
RECOMMENDED ARCHITECTURE 1995-2020
Transportion System Segment

FOR MISSION MODELS 1+I & 2+II

- EXISTING VEHICLES
  - STS TO 2010 - TITAN IV, MLV, AND OMV AS REQUIRED
- NEW VEHICLES



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LAUNCH VEHICLE CONCEPTS

	ELV/LCEE	ELV/FBB	STS II
			
PAYLOAD SIZE, FT	25D x 60L	25D x 60L	15D x 85L
WT - 28.5° x 150/150	115 Klb*	130 Klb*	65 Klb
28.5° x 220/220	112 Klb*	126 Klb*	60 Klb
90.0° x 150/150	102 Klb*	105 Klb*	35 Klb
VEHICLE LENGTH, FT	196	196/175	140/175
GLOW	2.8 Mlb	2.9 Mlb	3.2 Mlb
PROPULSION			
1st STAGE	(12) Castor V	(5) STBE	(5) STBE
2nd STAGE	(4) 220 Klb LCEE	(4) 220 Klb LCEE	(3) STME
ENGINE OUT CAPABILITY	YES	YES/YES	YES/YES
CROSSFEED	NO	NO	YES
L V MISSION RELIABILITY	0.989	0.993	0.997
DDT&E COST, $M	2249	0/8753	15,127/0

▨ NEW DEVELOPMENT * USING OTS WITH ISP = 320 SEC; MF = 0.8

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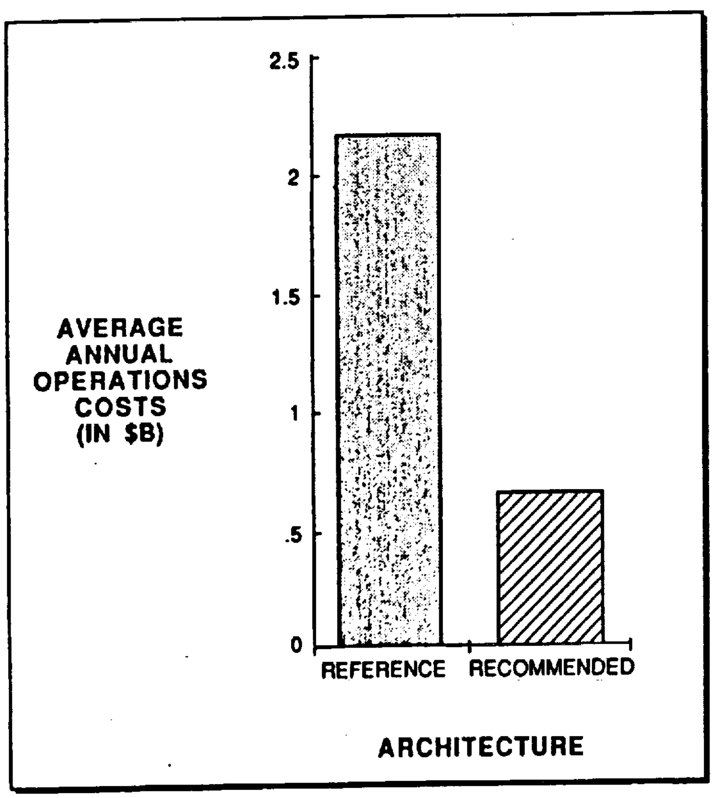
GROUND OPERATIONS FEATURES



KEYS TO MANPOWER REDUCTION

GROUND
- Efficient, Integrated Facilities
- Automated Management & Control
- Automated Test And Checkout
- Reduced Hazardous Processing
- Reduced Ground Support Equipment

VEHICLE
- Low Maintenance Thermal Protection
- Built-in-test On All Subsytems
- Electromechanical Versus Hydraulics
- Payload Standardization / Containerization
- Improved Accessibility & Modularization
- Reliable, Long Life Components

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VEHICLE TECHNOLOGY SUMMARY

VEHICLE TYPE	BASELINE	TRADE STUDY ALTERNATIVES
FULLY REUSABLE MANNED ORBITER IOC – 2005	CARBON-CARBON HOT STRUCTURE; LiAl TANKS; LO2/LH2 OMS/RCS; STME, 2-POS. NOZZLE; EM TVC	CROSSFEED VS. NO CROSSFEED (TS-116)
FULLY REUSABLE FLYBACK BOOSTER IOC – 1999	MACH 6 STAGING; HEATSINK LiAl STRUCTURE & TANKS; O2/H2 RCS; STBE (METHANE); EM TVC	ALTERNATIVE FUELS (TS-103) CROSSFEED VS. NO CROSSFEED (TS-116)
HYPERSONIC AIRBREATHER IOC – AFTER 2000	USE GOVT-DEFINED VEHICLE	NONE
SDV WITH PROPUL/ AVIONICS MODULE IOC – 1995	CONVENTIONAL AL STRUCTURE & TANKS; SSME-100%; HYDRAULIC TVC; BI-PROP OMS & RCS; PREC. RECRY	NONE
EXPENDABLE CORE (FLYBACK BOOSTER) IOC – 1999	LOW COST LiAl STRUCTURE & TANKS; N2H4 RCS; LCEE; EM TVC; P/L CIRC. BY SMM; CORE DEORBIT BY SRM	ENGINE OUT (TS-113) REUSABLE PAM (TS-114) FIXED VS. 2-POS NOZZLE (TS-115)
EXPENDABLE LAUNCH VEHICLE (STRAP-ON SRMs) IOC – 1999	SAME CORE AS ABOVE; CASTOR V SRMs WITH FWC; SSME - 100% → LCEE	ENGINE OUT (TS-113)
SINGLE STAGE TO ORBIT IOC – 2005	CARBON-CARBON HOT STRUCTURE; LiAl TANKS; LO2/LH2 OMS/RCS; STBE & STME, 2-POS. NOZZLE; EM TVC	VMRE VS. STBE & STME (TS 105)
MANNED GLIDER IOC – 2005	CARBON-CARBON HOT STRUCTURE; LO2/LH2 OMS/RCS; EM TVC	NONE

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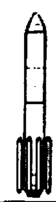
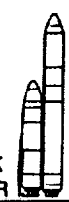
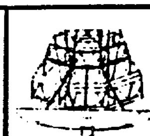
GENERAL DYNAMICS
Space Systems Division

TECHNOLOGY PROGRAM APPLICATIONS

DISCIPLINE	APPLIED TECHNOLOGY	 EARLY LAUNCH VEHICLE	 FLYBACK BOOSTER	 ORBIT TRANSFER VEHICLE	 SHUTTLE II ORBITER
AERO-THERMO-DYNAMICS	AEROBRAKING			X	
	PRECISION RECOVERY	X			
	FLIGHT / ENTRY RESEARCH		X		X
PROPULSION & POWER	LOX / HC ENGINES		X		X
	ADVANCED LOX / H2 MAIN ENGINE	X	X		X
	ADVANCED LOX / H2 OTV ENGINE			X	X
	SRM IMPROVE / REPLACE	X			
	ADVANCED POWER SYSTEMS	X	X	X	X
STRUCTURES & MATERIALS	EXPENDABLE TANKS & STRUCT	X			
	REUSABLE CRYOGEN TANKAGE		X	X	X
	REUSABLE VEHICLE STRUCTURE		X	X	X
AVIONICS	ADAPTIVE G N & C	X	X	X	X
	FLIGHT MANAGMENT SYSTEMS	X	X	X	X
	ADVANCED INFO PROCESSING	X	X	X	X
GROUND & FLIGHT OPERATIONS	EXPERT SYSTEMS	X	X	X	X
	AUTOMATED GROUND OPS	X	X	X	X
	ORBITAL SERVICING / OPS			X	X
	SBOTV OPERATIONS			X	
	AUTO SOFTWARE GENERATION		X	X	X

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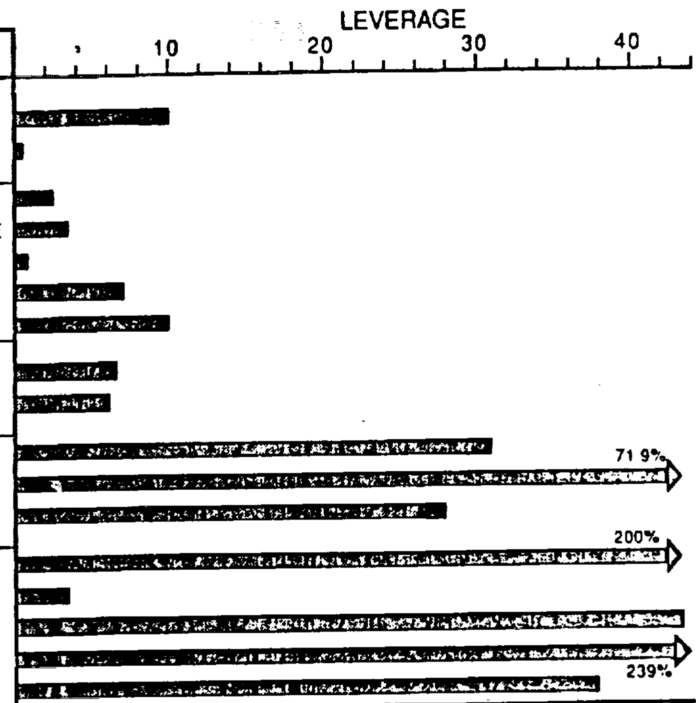
TECHNOLOGY PAYOFF COMPARISON

Technology Leverage

DISCIPLINE	APPLIED TECHNOLOGY
AERO-THERMO-DYNAMICS	AEROBRAKING PRECISION RECOVERY
PROPULSION & POWER	LOX / HC ENGINES ADVANCED LOX / H2 MAIN ENGINE ADVANCED LOX / H2 OTV ENGINE SRM IMPROVE / REPLACE ADVANCED POWER SYSTEMS
STRUCTURES & MATERIALS	EXPENDABLE TANKS & STRUCT REUSABLE VEHICLE STRUCTURE
AVIONICS	ADAPTIVE G N & C FLIGHT MANAGEMENT SYSTEMS ADVANCED INFO PROCESSING
GROUND & FLIGHT OPERATIONS	EXPERT SYSTEMS AUTOMATED GROUND OPS ORBITAL SERVICING / OPS SBOTV OPERATIONS AUTO SOFTWARE GENERATION



LEVERAGE: NET BENEFIT DIVIDED BY COST OF DEVELOPING AND IMPLEMENTING A NEW TECHNOLOGY

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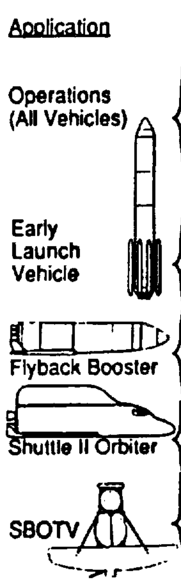
INTEGRATED TECHNOLOGY PLAN



Technology Programs (CY / FY)	87 / 87	88 / 88	89 / 89	90 / 90	91 / 91	92 / 92	93 / 93	94 / 94	95 / 95	96 / 96	97 / 97	98 / 98	PROGRAM COST ($M)
Adaptive G N & C	0.7	5.6	7.5	4.9	13.0	13.4	8.2	13.0	16.6	16.0	7.8		107
Multi-path Flight Mgmt. Syst.	1.4	11.3	14.8	7.4	19.1	18.9	9.8	15.6	19.9	19.2	9.3		147
Adv. Information Processing	2.1	16.9	22.1	9.8	25.3	24.5	11.4	18.2	23.2	24.2	10.9		187.
Expert Systems	0.4	1.4	1.1	4.3	21.5	20.9	9.8	15.6	19.9	19.2	9.3		123
Automated Ground Ops	0.7	7.6	11.8	11.4	19.1	18.9	9.8	15.6	19.9	19.2	9.3		143
Auto Software Generation	0.3	2.3	3.2	4.0	10.4	10.7	6.5	10.4	13.3	12.8	6.2		80
SRM Improve / Replace	3.2	7.6	6.2	4.0									21
Expendable Tanks & Struct	2.0	4.0	8.0	4.0									22
Adv LOX / H2 Main Engine	5.5	7.8	8.5	6.8	6.0	6.0	6.0	6.0	6.0	20.0	24.0		103
Precision Recovery	6.6	20.7	38.4	47.1									113
Adv. Power Systems	0.7	6.1	7.3	2.5	6.4	6.3	3.3	5.2	6.6	6.4	3.1		54
LOX / HC Engines	2.0	2.0	2.0	2.0	14.0	40.0							64
Reusable Cryogen Tankage	3.5	9.2	18.7	38.7	54.0	35.3	28.0	31.0	13.3	8.4	4.0		242
Advanced Reusable Struct.	3.5	12.0	20.0	29.0	47.3	50.3	21.3	33.9	43.1	41.7	20.2		322
Flight / Entry Research				0.7	0.7	7.0	23.3	49.0	100.0	100.0	100.0		380
Orbital Servicing Operations	0.1	2.0	6.0	20.0	33.0	30.0	35.0	12.0	6.0	3.0	3.0		150
Advanced OTV Engines	3.0	3.0	3.0	3.0	6.0	9.0	9.0	9.0	9.0	3.0	3.0		60
Aerobraking	0.1	15.0	40.0	55.0	27.0	26.0	22.0	20.0	14.0	9.0			230
SBOTV Operations	0.1	0.1	0.2	1.9	4.4	14.0	22.0	26.5	25.6	12.4			107
Annual Total ($M)	40	139	217	251	292	296	257	277	337	326	223		2654
Facility Total ($M)	14	129	210	162	82	54	32	10	5	5			703

Technology Readiness Milestones: ▽ ELV ▼ Flyback Booster ▼ Orbit Transfer Vehicle ▼ Shuttle II Orbiter

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SYSTEM LEVEL

- 100% Accessibility To Critical Components With Quick Change Subsystems And Main Engines
- Standardized Interfaces And Parts With Priority To High Reliability Standard Off-the-shelf Components
- Component Replacement Rather Than Repair In On-line Integration Flow
- Standardized Payload Canister Shroud Interfaces To Core Stage With Automated/Robotic Shroud Connections And No Shroud Separation Pyrotechnics
- Self Supporting Structure Without Internal Pressurization Or Bolt-on Support During Transport, Processing And Erection
- Integral or Plug-in GSE For Automated Final Checkout & Launch System
- Near All Weather Processing & Launch
- Precision Recovery Of PA Module At Launch Site With Little/No Damage
- Non-toxic Liquid Propellants
- No Nozzle Gimbal And Single Segment Solid Strap-on's
- Minimal Use Of Solid Propellants And Pyrotechnic Systems

SUBSYSTEM LEVEL

ENGINE DESIGN CRITERIA

1. Quick disconnects shall be provided for all electrical, propellant and fluid connections necessary for engine removal
2. The engine shall fit any position on the vehicle without reconfiguration.

STRUCTURE DESIGN CRITERIA

1. Hinged doors shall be used to provide quick access and to limit damage due to ground handling and wind loading
2. Access covers and doors shall be interchangeable between vehicles without modification or fitting

ELECTRICAL POWER SUPPLY DESIGN CRITERIA

1. Cable harnesses shall be designed so they can be factory built and installed as a unit.
2. Self Test/Built in Test shall be used to reduce fault isolation and functional checkout time (wrap-around tests).

AVIONICS DESIGN CRITERIA

1. Equipment shall be rack-mounted with hand-operated captive fasteners to hold LRU in place
2. Equipment with a high removal frequency shall be situated in convenient locations to facilitate maintenance
3. Self Test/Built-in-Test shall be used to reduce fault isolation and functional checkout time.

Figure 5.1.2.2-4. Design Requirements

Table 5.1.2.2-1. Design Implementation

OPERATIONS INFLUENCES	LEVEL OF IMPLEMENTATION	METHOD OF IMPLEMENTATION
Minimal Hazardous Operations	RCS System Payload Mechanical	RCS Fuel Type Consistent With Main Propulsion Payload Fueling Offline, Integrated Sealed Replace Pyrotechnics with Electromechanical / Laser Initiation
Simplified TPS	Core Flyback Booster Shuttle II	Robotically Applied Spray-on TPS Heat Sink High Temperature Materials
No Component Assembly at Launch Site	Core & F/B Booster Payload	Elements Completely Assembled and Tested in Manufacturing Built Up In Canister In Payload Processing Facility
Automated Test and Checkout	Avionics Mechanical Propulsion	Monitor and Dump System Expert System in GSE
Quick Change Cmpts (100% Access to Critical Components)	Avionics Mechanical	Hand Fasteners, Modular Components, Access Doors, Panels Self Sealing, Quick Disconnects
Adverse Weather	Structural	Vehicle Stressed for High Wind, High Shear Conditions Stable Vehicle Configuration
Ease of Transportation	Structural	Robust Structure (Self Supporting, No Pressure Stabilization) Sized For Ease Of Transportation, Collocated Facilities
Standardized Interfaces	Avionics Payload	Single Port Avionics Bus within Vehicle Vehicle/Payload,Core/Booster,Vehicle/Pad Standard Utility, Structural Mate, Modular Software
Minimize Servicing	Mechanical	Electromechanical Gimbal Actuators, Valves (vs. Hydraulic)

SYSTEM LEVEL

- Vehicle and payload interfaces; structural, communications and computer data support shall be limited and not required integration verification.
- Minimal ground monitoring of vehicle systems.
- No ground control, (except range) shall be required for unmanned vehicle during ascent. Minimal control for all flight phases of a manned vehicle.
- On-orbit navigation shall utilize GPS system.
- Standardized payload canister shroud interfaces to core stages with automated/robotic shroud connections.

SUBSYSTEM LEVEL

AVIONICS DESIGN CRITERIA

1. Distributed systems architecture shall be modular to allow for expansion and adaptation to new technology.
2. System / design architectures shall allow individual development of software modules, and not require integrated verification. Simple software redundancy management
3. Software shall be standardized and user friendly.
4. On board data analysis/compression shall limit telemetry downlink.
5. Telemetry limited to minimum requirement necessary for post flight failure or trend analysis.
6. High autonomy flight control shall be incorporated for all flight phases and contingencies.

STRUCTURAL DESIGN CRITERIA

1. Standard payload attach fittings/devices.
2. Over margined design - vehicle sized 20% over nominal payloads manifested

Figure 5.1.2.3-6 Vehicle Design Requirements

Table 5.1.2.3-1 MCS Influences On Vehicle Design

MISSION CONTROL INFLUENCES	LEVEL OF IMPLEMENTATION	METHOD OF IMPLEMENTATION ON VEHICLE
Minimal Flight to Flight Reconfiguration and Verification	Avionics Software	Distributed Architecture; Simple Redundancy Software (5 String); Stand-Alone, Standardized Software Modules for Each Flight Phase; Standard Vehicle Telemetry Format
Limit Vehicle to Payload Support and Verification	Avionics Core, STS II Structures Core	Separate Vehicle and Payload Software, Data Processing, and Communications Limited Interfaces Standardized Payload Canister Automated/Robotic Shroud Connections
Reduced Ground Monitoring	Critical Systems Flyback Booster Core, STS II	Telemetry Limited to Minimum for Trends, Failure Analysis; On-Board Data Analysis/Compression, Active Health Monitoring Systems
Minimal Ground Control	Flyback Booster STS II	High Autonomy Flight Control for All Flight Phases and Contingencies Adaptive GN&C Auto Self-Test and Fault Tolerance Management GPS Navigation Update
Reduced Trajectory and Flight Dynamics Analysis & Optimization	Core Flyback Booster STS II	10% Margin Over Required Launch Performance and Reserves - Engine Sizing, Structural Design Factors, etc.; Large OMS/RCS Prop. Margins; Axial Thrust Configuration (As Opposed To STS 1)
Reduced Operational Constraints (ie Landing Weight) & Complex Workarounds (ie Safe Propellant Residuals)	Core Flyback Booster STS II	Over-Margined Design and Modular Upgrade Capability for Crucial Systems, Including Electrical Power System, Computer System, Recovery Systems (i.e. Landing Gear & Brakes)

OPERATIONS INFLUENCES	LEVEL OF IMPLEMENTATION	METHOD OF IMPLEMENTATION
Minimal Hazardous Operations	RCS System Payload Mechanical	RCS Fuel Type Consistent With Main Propulsion Payload Fueling Offline, Integrated Sealed Replace Pyrotechnics with Electromechanical / Laser Initiation
Simplified TPS	Core Flyback Booster Shuttle II	Robotically Applied Spray-on TPS Heat Sink High Temperature Materials
No Component Assembly at Launch Site	Core & F/B Booster Payload	Elements Completely Assembled and Tested in Manufacturing Built Up in Canister in Payload Processing Facility
Automated Test and Checkout	Avionics Mechanical Propulsion	Monitor and Dump System Expert System in GSE
Quick Change Cmpts (100% Access to Critical Components)	Avionics Mechanical	Hand Fasteners, Modular Components, Access Doors, Panels Self Sealing, Quick Disconnects
Adverse Weather	Structural	Vehicle Stressed for High Wind, High Shear Conditions Stable Vehicle Configuration
Ease of Transportation	Structural	Robust Structure (Self Supporting, No Pressure Stabilization) Sized For Ease Of Transportation, Collocated Facilities
Standardized Interfaces	Avionics Payload	Single Port Avionics Bus within Vehicle Vehicle/Payload,Core/Booster,Vehicle/Pad Standard Utility, Structural Mate, Modular Software
Minimize Servicing	Mechanical	Electromechanical Gimbal Actuators, Valves (vs. Hydraulic)

Figure 9.4.2-1. Ground Operations Influence on Vehicle Design

MISSION CONTROL INFLUENCES	LEVEL OF IMPLEMENTATION	METHOD OF IMPLEMENTATION ON VEHICLE
Minimal Flight to Flight Reconfiguration and Verification	Avionics Software	Distributed Architecture; Simple Redundancy Software (5 String); Stand-Alone, Standardized Software Modules for Each Flight Phase; Standard Vehicle Telemetry Format
Limit Vehicle to Payload Support and Verification	Avionics Core, STS II Structures Core	Separate Vehicle and Payload Software, Data Processing, and Communications Limited Interfaces Standardized Payload Canister Automated/Robotic Shroud Connections
Reduced Ground Monitoring	Critical Systems Flyback Booster Core, STS II	Telemetry Limited to Minimum for Trends, Failure Analysis; On-Board Data Analysis/Compression, Active Health Monitoring Systems
Minimal Ground Control	Flyback Booster STS II	High Autonomy Flight Control for All Flight Phases and Contingencies Adaptive GN&C Auto Self-Test and Fault Tolerance Management GPS Navigation Update
Reduced Trajectory and Flight Dynamics Analysis & Optimization	Core Flyback Booster STS II	10% Margin Over Required Launch Performance and Reserves - Engine Sizing, Structural Design Factors, etc.; Large OMS/RCS Prop. Margins; Axial Thrust Configuration (As Opposed To STS I)
Reduced Operational Constraints (ie Landing Weight) & Complex Workarounds (ie Safe Propellant Residuals)	Core Flyback Booster STS II	Over-Margined Design and Modular Upgrade Capability for Critical Systems, Including Electrical Power System, Computer System, Recovery Systems (i.e. Landing Gear & Brakes)

Figure 9.4.2-2. Mission Control Influence on Vehicle Design

The recommended Technology Demonstration Programs and their relationship to the WACC listing is illustrated in Figure 5.1.3.1-2. The recommended technology programs are grouped within the major categories in the order of corresponding WACC technologies. A strong correlation between the two is indicated by the diagonal line of darkened squares within the matrix, which signify a direct correlation. Lighter squares, signifying partial correlation, are scattered more widely, illustrating the importance of coordination between the various development and demonstration programs.

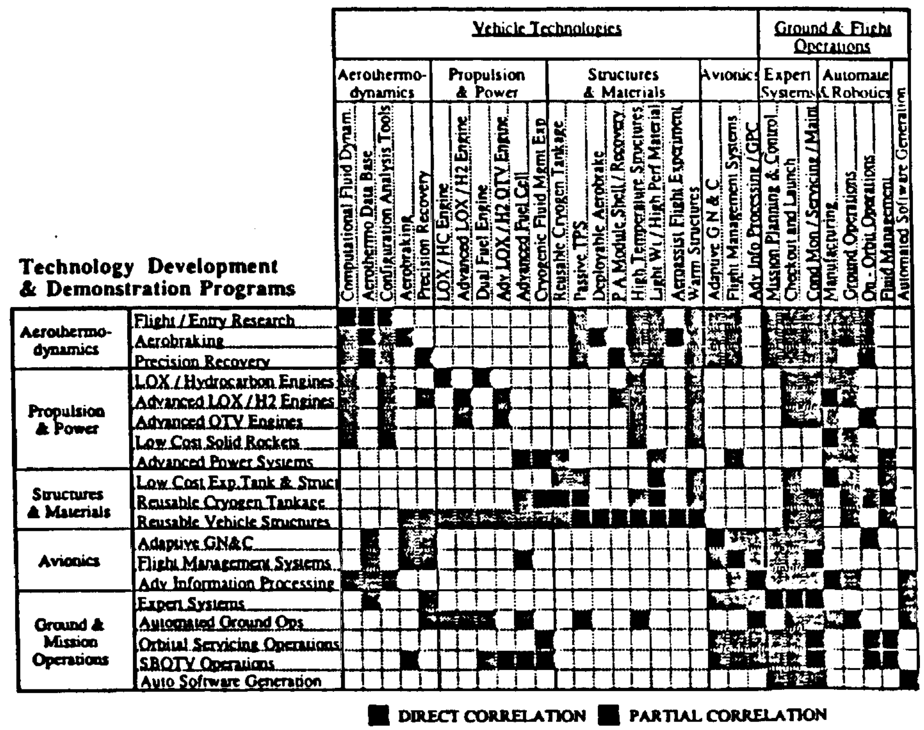

Figure 5.1.3.1-2 Recommended Technology Development and Demonstration Programs.

5.1.3.2 Technology for the Recommended Architecture. The Recommended architecture is

Table 5.1.2.2-9. Ground System Trade Summary

TRADE	OBJECTIVE	CONCLUSIONS
HORIZONTAL VS VERTICAL PROCESSING	[illegible]	• [illegible] • [illegible]
PRECISION RECOVERY	[illegible]	• [illegible] • [illegible]
BOOSTER PROPELLANT (STRAP-ON)	[illegible]	• [illegible] • [illegible] • [illegible] • [illegible]
LAUNCH PAD ERECTION	[illegible]	• [illegible]

Table 5.1.2.2-10. Payload Interface Criteria

PAYLOAD INTERFACE	CRITERIA
• Power	Standardized (28 V) simple connection
• Cooling	No requirement, or umbilical if necessary
• Fueling	No top off after encapsulation, except cryogenics at the pad during vehicle fueling
• Calibration	No access after encapsulation except electronically via data buss
• Health monitoring	Single data buss, channels limited to TBD
• Connectors, mountings	Standardized per TBD
• AGE*	Weight (~15%) included in P/L allowance
• Cleanliness	Clean room of 100K or greater
• Integration with L/V*	No earlier than 120 hrs of launch
• Emergency access at pad	Only for less than 6 hour delay for minor repair

* Part of STAS groundrule list.

Table 8-1. Insights Obtained Through Architecture Trade-off and Evaluation

Significant Finding	Consequence Of Finding On Architecture Recommendation
Life-cycle cost is very sensitive to launch rates, and insensitive to extra vehicle payload capability.	Develop vehicles with larger payload capability than required by the nominal mission model.
SSTO is not a cost-effective solution for Shuttle II.	Develop a two-stage Shuttle II.
Architecture LCC is very sensitive to reliability values.	Incorporate all feasible reliability features into new vehicle designs.
A significant number of new facilities are needed by 1995 to meet the mission requirements.	Immediately begin the budgetary process to initiate a facilities construction program with a high launch rate capability requirement.
Ground processing and mission control manpower peak requirements occur as new systems are being phased in and current systems must remain operational.	Study this transition phase in more detail to determine ways in which peak manpower requirements might be mitigated.
Operations cost reductions can be made in the areas of direct manpower, indirect manpower, and facilities maintenance.	Make the up-front investment necessary to realize the operations cost reductions that are possible.
Existing launch sites are capable of meeting the mission model needs if new facilities are built and turnaround time goals are met.	Prepare to fully utilize existing launch site capabilities. Continue to study alternate launch sites.
If properly time-phased, early funding for the recommended architecture does not significantly exceed funding for performing the mission model using existing vehicles (*i.e.*, the reference architecture).	Use the following IOCs: ELV 1993-1995 Down-cargo Stage 1995-1998 Flyback Booster 1998-2000 STS II Orbiter 2004-2006
Development of a down-cargo vehicle reduces risk to man and provides assured access.	Develop a down-cargo vehicle as early as practicable.
Upper stage costs are not major contributors to architecture life-cycle cost.	The SBROTV can be included in the architecture for a small investment relative to the architecture LCC. Benefits include world leadership and technology spin-offs.

BOOSTER PROPELLANT TRADE STUDY

COMPARISON

• VEHICLE CHARACTERISTICS	LH2	CH4	RP-1
• MAIN ENGINES	(7) SSME DERIV.	(5) STBE	(6) STBE
– PROPELLANTS	LO2/LH2	LO2/CH4/LH2 AUG	LO2/RP-1
– MIXTURE RATIO	7.0	3.64	2.53
– ISP VAC	426	369	326
• ABES	(14) CF-34	(12) CF-34	(12) CF-34
• DRY WEIGHT, LB	322 K	259 K	274 K
• PROPELLANT WT, LB	1.80 M	2.00 M	2.38 M
• STEP WT, LB	2.16 M	2.29 M	2.69 M
• ORBITER GROSS WT, LB	954 K	954 K	954 K
• VEHICLE GLOW, LB	3.12 M	3.25 M	3.64 M
• COST COMPARISON ('86 $)			
• DDT&E	6.7 B	8.8 B	6.8 B
• PRODUCTION (6 UNITS)	5.5 B	4.8 B	4.0 B
• ETR LAUNCHES (388 FLTS)*	12.7 B	12.6 B	12.9 B
• WTR LAUNCHES (69 FLTS)*	8.3 B	8.4 B	8.5 B
• TOTAL INVESTMENT	12.1 B	13.6 B	10.8 B
• TOTAL RECURRING*	21.0 B	21.0 B	21.4 B
• TOTAL BOOSTER LCC*	33.2 B	34.6 B	32.2 B

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* INCLUDES STS II ORBITER RECURRING COSTS

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SUMMARY OF MAJOR TRADE STUDY RESULTS

TRADE STUDY	PRIMARY FINDINGS
1. LAUNCH VEHICLE SIZING	SELECTED PAYLOAD SIZES • STS II 65 K • ELV 115 K • ELV/FBB 130 K
2. TWO STAGE VS. SSTO	TWO STAGE PREFERRED OVER SSTO
3. LOX/H2 VS LOX/HC BOOSTER PROPELLANT	NO DECISION YET – MORE ANALYSIS NEEDED
4. ENGINE OUT	ENGINE OUT CAPABILITY SELECTED
5. EXPENDABLE CORE VS. P/A MODULE	EXPENDABLE CORE SELECTED
6. SPACE BASING/SPACE PLATFORMS	EVOLUTION FROM EOTV (1995) TO SBOTV (2002) RECOMMENDED.
7. HORIZONTAL VS VERTICAL INTEGRATION	VERTICAL INTEGRATION RECOMMENDED
8. MISSION CONTROL BASING	PARTIALLY DISTRIBUTED RECOMMENDED

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Table 5.1.3.3-1 Technology Program Benefits

TECHNOLOGY PROGRAMS	BENEFITS TO ARCHITECTURE
Flight/Entry Research	Allows testing of prototype Shuttle II subsystems in a relevent environment prior to full scale development
Aerobraking	Reduces ΔV requirements for OTV missions, increases payload significantly and/or reduces OTV propellant
Precision Recovery	Recovers engines and avionics (about half of the hardware cost) from partially reusable vehicles
LOX/Hydrocarbon Engines	Reduces complexity and weight of flyback booster propulsion systems, reduces booster DDT&E cost
Advanced LOX/H2 Main Engine	Develops expendable engine materials and producibility, improves the maintainability and lifetime of reusable engines
Advanced LOX/H2 OTV Engine	Increases specific impulse for engine with retractable nozzles for aerobraking, designed for maintenance in orbit
SRM Improvement/Replace	Reduces cost through inexpensive propellant formulations and computer integrated manufacture, clean propellant
Advanced Power Systems	Replaces hydrazine APU/hydraulics, with attendant manpower and safety benefits; lighter weight for reusable vehicles
Expendable Tanks & Structures	Achieves lower cost through computer integrated manufacture, reduces weight (increases payload) through advanced materials
Reusable Cryogen Tankage	Enables reusable vehicles (Flyback Booster, STS II, and OTV), ensures safe reuse of advanced tankage.
Reusable Vehicle Structures	Reduces weight of structure through increased temperature range (with less TPS) and higher strength (greater payload).
Adaptive GN&C	Allows launch in adverse weather with less preplanning, accommodates anomalies, reduces MCS manpower needs
Flight Management Systems	Improves reliability, primarily for Shuttle II, reduces manpower required for mission control through autonomy
Advanced Information Processing	Reduces documentation and allows rapid data access for design, manufacturing, testing, and operations
Expert Systems	Reduces manpower per flight through applications in mission planning and monitoring, and in ground operations
Automated Ground Operations	Reduces manpower or launch and turnaround through automated test and checkout, and by robotic systems
Orbital Servicing Operations	Reduces number of launches and payloads by servicing rather than reconstitution, fluid transfer for SBOTV also
SBOTV Operations	Avoids additional launch vehicles and operations for GBOTV, allows light OTV structure, reduces total mass launched
Automated Software Generation	Reduces manpower required for software generation, validation and management; decreases reconfiguration time

	CURRENT VEHICLES	NEW CARGO VEHICLE	MANNED VEHICLE	ORBIT TRANSFER VEHICLE
VEHICLE				
AEROTHERMODYNAMICS				
COMPUTATIONAL FLUID DYNAMICS	-	X	X	X
AEROTHERMO DATA BASE	-	X	X	X
CONFIGURATION ANALYSIS TOOLS	-	X	X	X
AEROBRAKING	-	-	-	X
PRECISION RECOVERY	-	X	-	-
PROPULSION & POWER				
LOX/HC ENGINE	-	X	X	-
ADVANCED LOX/H2 ENGINE	-	X	X	-
DUAL FUEL ENGINE	-	X	X	-
ADVANCED LOX/H2 OTV ENGINE	-	-	-	X
ADVANCED FUEL CELL	X	X	X	X
CRYOGENIC FLUID MANAGEMENT	-	-	X	X
STRUCTURE & MATERIALS				
REUSEABLE CRYOGEN TANKAGE	X	X	X	-
PASSIVE THERMAL PROTECTION SYSTEMS	-	X	X	-
DEPLOYABLE AEROBRAKE	-	-	-	X
PROP./AVIONICS MODULE SHELL/RECOVERY	-	X	-	-
HOT STRUCTURES	-	X	X	-
LIGHTWEIGHT/HIGH PERFORMANCE MATERIAL	-	X	X	X
AEROASSIST FLIGHT EXPERIMENT	-	-	-	X
WARM STUCTURES	-	X	X	-
AVIONICS				
ADAPTIVE GN&C	X	X	X	X
FLIGHT MANAGEMENT SYSTEMS	X	X	X	X
ADVANCED INFORMATION PROCESSING/GPC	X	X	X	X
OPERATIONS				
AUTONOMOUS EXPERT SYSTEMS				
MISSION PLANNING & CONTINGENCY	X	X	X	X
CHECKOUT & LAUNCH	X	X	X	X
CONDITION MONITORING/SERVICING/MAINT	X	X	X	X
AUTOMATION & ROBOTICS				
MANUFACTURING	X	X	X	X
GROUND OPERATIONS	X	X	X	X
ON-ORBIT OPERATIONS	X	X	X	X
FLUID MANAGEMENT	-	-	X	X
AUTOMATED SOFTWARE GENERATION	X	X	X	X

Figure 7.1.1.1-1 The WACC list of technologies is applicable to generic vehicle types.

6.8.3 MARTIN

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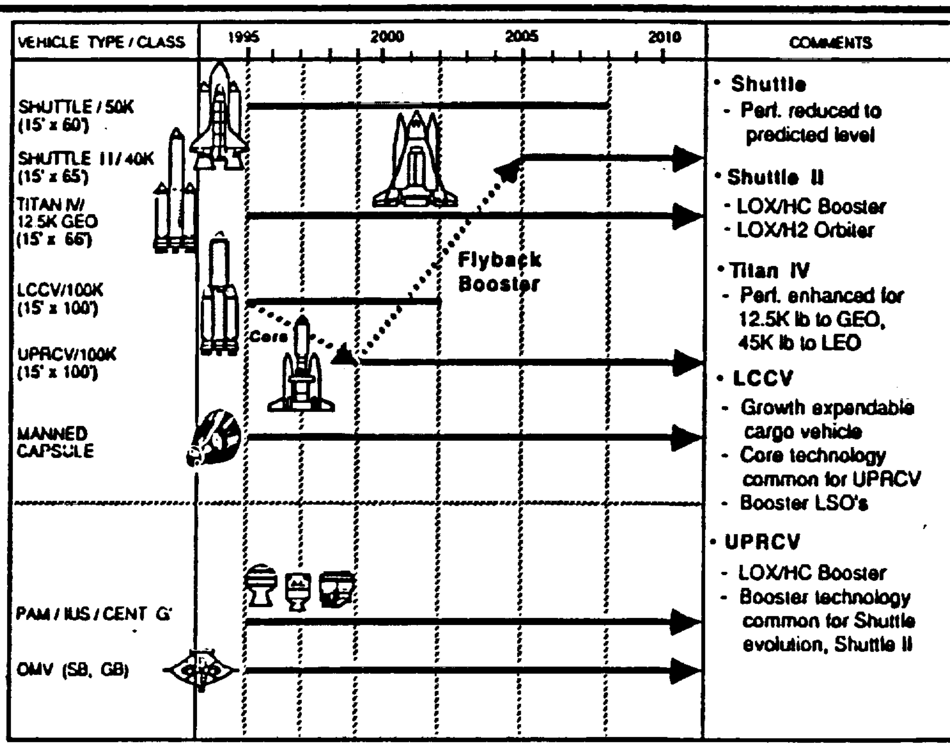
ARCHITECTURE OVERVIEW

VEHICLE ELEMENT	GROUND ELEMENT	FLIGHT ELEMENT	APPLIED TECHNOLOGIES
SHUTTLE I • LOX/H2 stage combust. with solid strap-ons • Derivative avionics	• Existing elements • Modular SRBs • Launch sites exist	• Derivative avionics • Limited on-board checkout • LCC & MCCs exist • COMM/network support adequate	• Expert systems applications • Adaptive GN&C • Advanced info processing/GPC • Auto S/W gen. & verif.
TITAN IV • Storable core with solid strap-ons • Derivative avionics • Enhanced performance	• Existing elements • Modular SRMs • Launch sites exist	• Derivative avionics • Limited on-board checkout • LCCs exist but upgraded • COMM/network support adequate	• Expert systems applications • Adaptive GN&C • Advanced info proc/GPC
LCCV • Cryo tanks • LOX/HC booster engines • Modified SSME in core	• Paperless processing • High rate vehicle processing • Expert systems for checkout	• Adaptive GN&C • Automated data handling • Improved planning • Expert systems for autonomy • Expendable facilities growth for support	• Expert systems applications • Adaptive GN&C • Manufacturing • Advanced info proc./GPC
UPRCV • Reusable cryo tanks • Flyback booster • P/A module for upper stage • Reusable engines in both stages • Core common with LCCV	• All weather operation • Flyback booster, P/A module return • Reusable engines • Horizontal assembly • Paperless processing • Expert systems for checkout	• Precision recovery/flyback • Automated data handling • Flight mgmt system & techniques • Expert systems for autonomy • Adaptive GN&C & GPS I/F • Planning standardization • New complimentary facilities with STS/II	• Expert systems applications • Adaptive GN&C • Manufacturing • Advanced info proc./GPC • Lt wt/high perf. materials
SHUTTLE II • Reusable cryo tanks • Flyback booster common with UPRCV • Long life engines	• All weather operation • Flyback booster & orbiter • Horizontal assembly • Long life engines • Paperless processing • Expert systems for checkout	• Expert systems for autonomy • Flight mgmt. system & techniques • Automated data handling • Adaptive GN&C & GPS I/F • Planning standardization • Consolidated organization	• Expert Systems applications • Adaptive GN&C • Manufacturing • Advanced info proc/GPC • Lt wt/high perf. materials

RECOMMENDED ARCHITECTURE - TRANSPORTATION SYSTEMS



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DESIGN FEATURES AND TECHNOLOGIES - LCCV

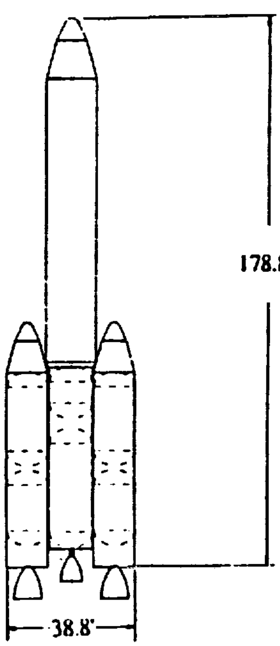
GENERAL
- ALL ELEMENTS ARE EXPENDABLE
- 2 STAGE CONFIGURATION USING LRB's
- 15' D. X 100' L. USABLE P/L BAY

PROPULSION
- ADVANCED HIGH PRESSURE ENGINES USING LOX/LH2 IN UPPER STG AND LOX/CH4 IN LRB's
- AL-LI 2090 TANKS WITH IMPROVED SURFACE INSULATION
- MINIMAL USE OF PYROTECHNICS FOR SEPARATION

STRUCTURE
- COMPOSITES USED FOR P/L FAIRING AND SECONDARY STRUCTURES
- 2219 AND 2014 AL USED IN PRIMARY STRUCTURES

AVIONICS AND OTHER
- MODULAR AVIONICS SYSTEM WITH LIMITED ADAPTIVE GUIDANCE AND CONTROL
- INERTIAL GUIDANCE ONLY
- UMBILICAL INTERFACE AT BASE OF VEHICLE
- "COCOON" TYPE OF P/L CONTAINER

LCCV-LOW COST CARGO VEHICLE



CHAR. \ CONFIG.	LCCV-100K STAGE 1	STAGE 2
PROPELLANT TYPE	LOX/CH4	LOX/LH2
Isp (VAC)	363.4	455.3
THRUST	1.94M	394K
NO. OF ENGINES	1	1
STAGE WT	1.01M	239K
PROPELLANT WT	947K	221K
INERT WT	58.8K	16.6K
MASS FRACTION	.92	.92
PAYLOAD	100K	
P/L BAY DIM.	15' X 100'	
P/L SHROUD WT	21K	
BURN TYPE	SERIES	
GLOW	1.37M	

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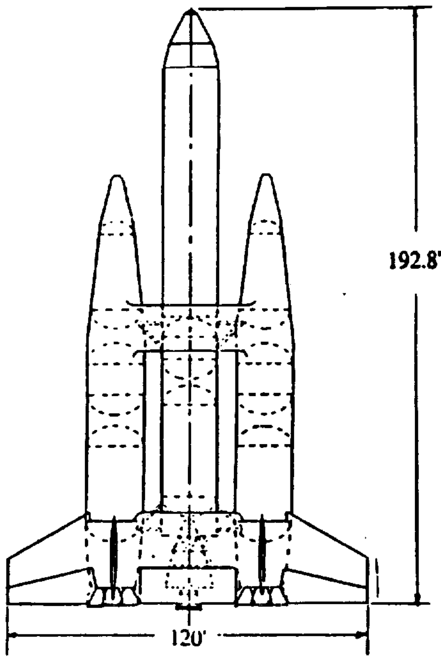
UPRCV-UNMANNED PARTIALLY REUSABLE CARGO VEHICLE



CHAR. \ CONFIG.	UPRCV-100K STAGE 1	STAGE 2
PROPELLANT TYPE	LOX/CH4	LOX/LH2
Isp (VAC)	363.4	455.3
THRUST	2.82M	394K
NO. OF ENGINES	3	1
STAGE WT	1.61M	258K*
PROPELLANT WT	1.45M	221K
INERT WT	166K	37.4K*
MASS FRACTION	.90	.86
PAYLOAD	100K	
P/L BAY DIM.	15' X 100'	
P/L SHROUD WT	21K	
BURN TYPE	SERIES	
GLOW	1.99M	

* INCLUDES P/A MODULE

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DESIGN FEATURES AND TECHNOLOGIES - UPRCV

PROPULSION

- ADVANCED, LONG-LIFE, HIGH PRESSURE ENGINES USING LOX/LH2 IN UPPER STAGE AND LOX/CH4 IN BOOSTER
- AL-LI 2090 MAIN TANKS WITH LONG-LIFE INTERNAL INSULATION
- FLYBACK ENGINES FOR REUSABLE BOOSTER
- P/A MODULE HAS BUILT-IN OMS/RCS
- APS USES SAME PROPELLANTS AS MPS

STRUCTURES AND TPS

- COMPOSITE INTERTANK ON BOOSTER AND SOME SECONDARY STRUCTURES. USE OF XD AND OTHER SUPER ALLOYS IN PRIMARY STRUCTURE AND TPS
- AERO SURFACES ARE HOT/WARM STRUCTURES OF COMPOSITES AND/OR ADVANCED ALLOYS
- METALLIC HONEYCOMB SANDWICH EXTERIOR PANELS WITH INSULATION AND ACTIVE COOLING PROVIDE DURABLE TPS
- P/A MODULE USES ACC FOR TPS
- COMPOSITE PAYLOAD FAIRING

AVIONICS

- AVIONICS PROVIDE ADAPTIVE GUIDANCE AND CONTROL FOR AUTONOMOUS OPERATION USING INERTIAL AND GPS
- FAULT-TOLERANT ELECTRICAL SYSTEMS

OTHER SYSTEMS

- UMBILICAL INTERFACES ARE AT BASE
- ELECTROMECHANICAL SERVOS AND/OR UNITIZED HYDRAULICS FOR ACTUATORS
- BOOSTER AND P/A MODULE RETURN TO LAUNCH SITE
- ON-BOARD EXPERT SYSTEMS (MINIMUM)

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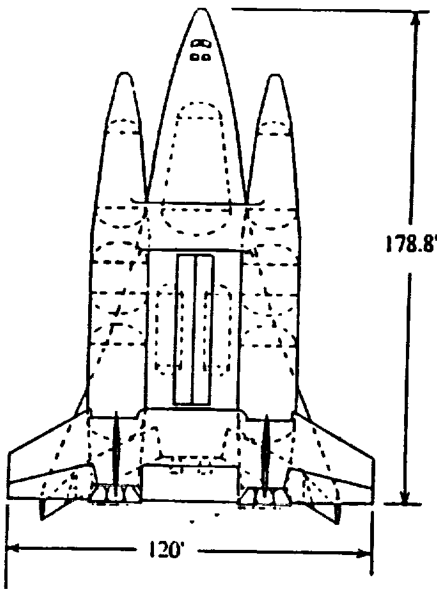
STS II



CHAR. \ CONFIG.	STS II - 40K STAGE 1	STAGE 2
PROPELLANT TYPE	LOX/CH4	LOX/LH2
Isp (VAC)	363.4	455.3
THRUST	3.25M	749K
NO. OF ENGINES	3	2
STAGE WT	1.61M	641K
PROPELLANT WT	1.45M	482K
INERT WT	166K	159K
MASS FRACTION	.90	.75
PAYLOAD	40K	
P/L BAY DIM.	15' X 65'	
P/L SHROUD WT	N/A	
BURN TYPE	SERIES	
GLOW	2.29M	

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DESIGN FEATURES AND TECHNOLOGIES - STS II

PROPULSION

- ADVANCED, LONG-LIFE, HIGH PRESSURE ENGINES USING LOX/LH2 IN ORBITER AND LOX/CH4 IN BOOSTER
- AL-LI 2090 MAIN TANKS WITH LONG-LIFE INTERNAL INSULATION
- FLYBACK ENGINES FOR REUSABLE BOOSTER
- APS USES SAME PROPELLANTS AS MPS
- MAIN ENGINES USED AS OMS IN ORBITER

STRUCTURES AND TPS

- COMPOSITE INTERTANK ON BOOSTER AND SOME SECONDARY STRUCTURES. USE OF XD AND OTHER SUPER ALLOYS IN PRIMARY STRUCTURE AND TPS
- AERO SURFACES ARE HOT/WARM STRUCTURES OF COMPOSITES AND/OR ADVANCED ALLOYS
- METALLIC HONEYCOMB SANDWICH EXTERIOR PANELS WITH INSULATION AND ACTIVE COOLING PROVIDE DURABLE TPS

AVIONICS

- AVIONICS PROVIDE ADAPTIVE GUIDANCE AND CONTROL FOR AUTONOMOUS OPERATION USING INERTIAL AND GPS
- FAULT-TOLERANT ELECTRICAL SYSTEMS

OTHER SYSTEMS

- UMBILICAL INTERFACES ARE AT BASE
- ELECTROMECHANICAL SERVOS AND/OR UNITIZED HY-DRAULICS FOR ACTUATORS
- ORBITER AND BOOSTER RETURN TO LAUNCH SITE
- ON-BOARD EXPERT SYSTEMS (EXTENDED)

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VERTICAL VS. HORIZONTAL CONCEPTS (REF) *

PRO VERTICAL

- ** • MAX UTILIZATION OF EXISTING FACILITIES
- *** • BEST WORKING CONDITIONS/PROTECTION OF PERSONNEL, SE, VEHICLE FROM WEATHER AND CONTAMINATION
- • IN-PROCESS MODS EASIER TO INSTALL
- *** • ADDITION OF DAMPER ARM (OR LIKE) WITHOUT INCREASE IN PAD TIME
- • LESS SENSITIVE TO FACILITY REQUIREMENTS DUE TO CHANGE IN LAUNCH RATES
- • LESS VEHICLE DESIGN PROBLEMS (NEG. LOAD MTG ATTCH, TOW DOLLY ATTCH, ETC.)
- ** • LESS FACILITY DEVELOPMENT PROBLEMS
- *** • NOT APPEAR PRACTICAL TO DO PROP/MECH D/O AND MAINT HORIZ
- *** • PAD NOT DRASTICALLY DIFFERENT FROM SATURN V/COULD INTERCHANGE IF REQ'D
- • VERT PROCESSING PROBLEMS WELL KNOWN/HORIZONTAL SPECULATIVE
- *** • BEST METHOD OF C/O IF ON-BOARD AUTONOMY BEGINS TO BE RELOCATED TO GROUND (GSE) (GSE CAN BE ON LUT AND NOT IMPACT PAD TIME)

* REF: SPACE SHUTTLE ERECTION, MATING, AND TRANSPORTING STUDY, JUNE 10, 1971
** APPLIES TO KSC/APOLLO FACILITIES ONLY
*** TURNED OUT TO BE BAD ASSUMPTIONS FOR STS FINAL CONFIGURATION

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VERTICAL VS. HORIZONTAL CONCEPTS (REF) *

PRO HORIZONTAL (REASONS FOR LOWER COST @ NEW SITE)

- • LOWER INTEGRATION BUILDING
- • LOWER INVESTMENT IN TOW WAY VS. CRAWLERWAY
- • NO CRAWLER REQUIRED
- • DEBUGGING ERECTION NOT APPRECIABLE, MORE TIME CONSUMING OR RISKY THAN NEW OPTIMIZED CRAWLER/LUT/PAD/VAB
- • CREW SIZING MORE EFFICIENT
- • LESS FACILITY MOD RISK DUE TO VEHICLE SIZE GROWTH/CONFIG CHANGE
- ** • FACILITIES COULD BE OPTIMIZED FOR SHUTTLE

* REF: SPACE SHUTTLE ERECTION, MATING, AND TRANSPORTING STUDY, JUNE 20, 1971
** COULD ALSO APPLY TO NEW VERTICAL SITE

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TECHNOLOGY IMPACT MATRIX - STAS OVERVIEW

TECHNOLOGY OPPORTUNITIES IN MAJOR DISCIPLINES	GROUND OPERATIONS	MISSION OPERATIONS	VEHICLE DESIGN
AEROTHERMODYNAMICS			
Computational Fluid Dynamics			X
Aerothermodynamics Data Base		X	X
Configuration Analysis Tools			X
Aerobraking		X	X
Precision Recovery	X	X	X
PROPULSION/POWER			
LOX/HC Engine	X		X
Advanced LOX/H2 Engine	X		X
Dual Fuel Engine	X		X
Advanced LOX/H2 OTV Engine			X
Advanced Fuel Cell	X	X	X
Cryogenic Fluid Mgmt. Expmt.		X	X
AVIONICS			
Adaptive GN&C		X	
Flight Mgtm. System		X	
Advanced Info Processing/GPC		X	
AUTO SOFTWARE GENERATION			
Auto S/W Gen. & Verification	X	X	

MAJOR COST REDUCTION POTENTIAL

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TECHNOLOGY IMPACT MATRIX - STAS OVERVIEW (CONCLD)

TECHNOLOGY OPPORTUNITIES IN MAJOR DISCIPLINES	GROUND OPERATIONS	MISSION OPERATIONS	VEHICLE DESIGN
STRUCTURES & MATERIALS			
Reusable Cryogenic Tanks			X
Passive (Cryo) TPS	X		X
Deployable Aerobrake		X	X
P/A Module Shell/Recovery	X	X	X
High Temp. Structure			X
Light Wt/High Perf. Materials			X
Aero Assist Flt. Expmt.		X	X
Warm Structures			X
GROUND & FLIGHT OPS - AUTONOMOUS EXPERT SYS.			
Mission Planning & Control		X	
Checkout & Launch	X	X	
Condition Monit./Service/Maint.	X	X	
AUTOMATION & ROBOTICS			
Manufacturing			X
Ground Operations	X		
On-Orbit Operations		X	
Fluid Management		X	X

MAJOR COST REDUCTION POTENTIAL

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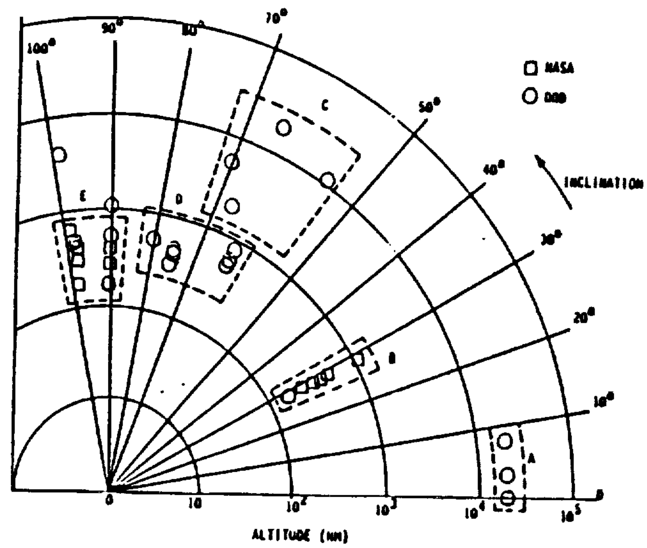
MISSION DESTINATIONS (CIVIL II + DOD 2)

A - GEOSYNCHRONOUS AND NEAR-GEOSYNCHRONOUS
B - SPACE STATION ORBIT AND VICINITY
C - MID-INCLINATION RANGE, HIGH ALTITUDE (>1000NM)
D - MID-INCLINATION RANGE, LOW ALTITUDE (<1000NM)
E - LOW-EARTH POLAR AND SUN-SYNCHRONOUS



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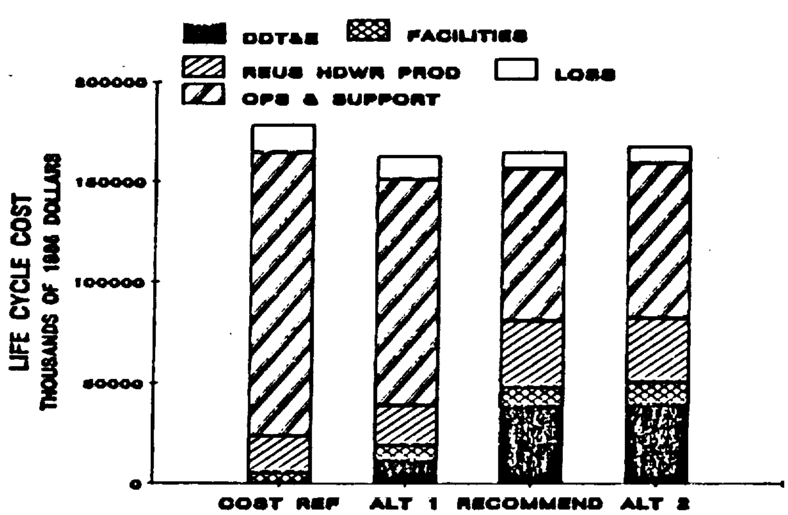
TOTAL LIFE CYCLE COST DISTRIBUTION



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ARCHITECTURE BENEFITS FROM APPLICATION OF ADVANCED TECHNOLOGY

	BENEFITS
GROUND OPERATIONS:	
Application of Autonomous Expert Systems to Vehicle Checkout, Launch, Servicing and Maintenance	Increased productivity, lower skill requirements Improved vehicle status info, data assimilation and trend analysis Increased vehicle autonomy, reduced turnaround time Reduced costs, improved scheduling, rapid problem response
Auto S/W Generation and Verification	Reduced software development/production costs Reduced potential for system errors, reduced software maintenance Improved configuration management
Advanced Info Processing/GPC	Increased computational performance, capability for expert systems Improved checkout capability, reduced vehicle turnaround time Improved vehicle autonomy, flexibility, and fault tolerance
Automation and Robotics	Increased productivity, reliability and safety of testing and checkout Limited investment required, can focus on applications for specific tasks now
Passive TPS	Lower maintenance and refurbishment costs, improved scheduling and vehicle turnaround time
MISSION OPERATIONS:	
Application of Expert Systems to Mission Planning and Control and Condition Monitoring	Improved vehicle information and data assimilation Increased vehicle autonomy, flexibility, and reconfiguration capability Improved resource management, standard consistent decision making, and reliability Decreased level of effort per flight, lower skill requirement and training
Adaptive GN&C	Enhanced robustness for adverse weather operation Improved operational readiness, targeting and retargeting duation, and mission success Increased vehicle autonomy, flexibility and fault tolerance
Advanced Info Processing/GPC	Improved onboard checkout capability and fault tolerance Increase computational performance, expert system capability Improved vehicle autonomy, flexibility
Auto S/W Generation & Verification	Reduced software development/production costs Reduced potential for system errors, reduced software maintenance Improved configuration management
Flight Management System	Improved operational efficiency, productivity Reduced monitoring and communication support, improved logistics support Reduced contingency planning and training, system reconfiguration
Automation & Robotics (On-Orbit)	Reduce dedicated support elements, increase productivity Reduce operations complexity, incorporate standardization Supports space basing and improves resource scheduling
VEHICLE DESIGN:	
Reusable Cryogenic Tankage	Reduced vehicle weight and size, hardware cost savings Improved vehicle performance using cryo fuels
LOX/HC Engine	High density fuel enables smaller, lighter tanks Smaller vehicle facilitates ground handling
Light Weight/High Perf. Materials	Greater strength/performance with less weight, reduced vehicle weight Reduced fabricating complexity and cost Reduced maintenance costs and time, extended service life
Precision Recovery	Efficient flyback booster and P/A module, reusable hardware cost savings Reduced support operations and turnaround time Improved flexible terminal landing phase operations
Manufacturing (Automation & Robotics)	Vehicle production cost savings, CIM systems, paperless factory Improved scheduling, flexibility and logistics support

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IMPROVED GROUND PROCESSING AND MISSION OPERATIONS WITH EXPERT SYSTEMS APPLICATIONS

TECHNOLOGY OVERVIEW

- Description: Develop and apply expert systems to performing predictable, routine functions automatically thereby increasing operator efficiency, productivity and response in labor-intensive operations and checkout functions resulting in significantly lower operating costs.
- Objectives:
  - Improve vehicle status information and selection
  - Apply expert systems to rapidly identify problems and provide solutions
  - Provide increased vehicle and system autonomy
  - Reduce launch and checkout dependency on mission operations
  - Reduce skill level and manpower investment commitments for condition monitoring and maintenance
  - Provide performance trend analysis to order maintenance
  - Reduce costs of high-frequency launch operations
- Approach:
  - Perform complete mission functional analysis
  - Construct mission/system model
  - Acquire applications of knowledge base to convert to programmed logic
  - Determine performance capabilities and develop management techniques

TECHNOLOGY ASSESSMENT

- State-of-the-Art:
  - Ground processing technology and concepts have been developed, but require focused application
  - Expert systems successfully applied on limited scale in commercial industry
  - NASA, DoD and DARPA working to define boundaries and develop applications
  - No unifying standards for development, display and interface
  - Systems relatively slow; high cost of knowledge acquisition
- Application:

  Vehicle Design:
  - Flexible manufacturing, vehicle assembly
  - Subsystem fault isolation and control
  - Automated S/W development

  Ground Operations:
  - Propellant loading, hazardous operations
  - Vehicle test and checkout

  Mission Operations:
  - Navigation, recovery and traffic management
  - Mission planning, system monitoring and control
- Risk:
  - Medium schedule and cost
  - Increase in system complexity and impact to real time application
  - Must prove reliability of expert systems in critical applications

QUALITATIVE TECHNOLOGY BENEFIT

- Relieve human operator of tedious and time-consuming tasks
- Higher reliability performance by lower skilled personnel
- Improved and timely data assimilation
- Improved personnel productivity, lower operations costs
- Greater vehicle autonomy and reduced vulnerability
- Reduced vehicle turnaround time

QUANTITATIVE BENEFITS ANALYSIS

- IRR: 36%*
- % LCC: 7%*
- Leverage: 11*

*Based on SDI architecture analysis

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MLG133/IPKS

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ADAPTIVE GUIDANCE, NAVIGATION & CONTROL (GN&C) TECHNOLOGY PROGRAM

TECHNOLOGY OVERVIEW

- Description: Develop GN&C algorithms which adapt to mission variables by automatically adjusting parameters in response to measured real time performance versus desired standards
- Objectives
  - Efficient use of full vehicle design envelope
  - Optimized thrust vector control
  - Optimum reaction controls fuel usage
  - Automatically maintain flying qualities critical to safety
  - Reduced vehicle systems design, test and checkout costs
  - Lower mission support costs
  - Incorporate fault tolerance in adaptive systems
- Approach
  - Identify variables for adaption system compensation
  - Prioritize variables
  - Develop algorithms for GN&C performance vs. criteria
  - Determine vehicle transient/steady state characteristics
  - Develop fixed base simulator for evaluation

TECHNOLOGY ASSESSMENT

- State-of-the-Art:
  - Extensive flight testing conducted on aircraft
  - Shuttle uses simple adaptive control during ascent phase
  - IUS design includes simple adaptive guidance
  - Onboard digitial computer enables implementation
- Application:

  Ground Operations:
  - Improved readiness, reduced launch turnaround time (20%)

  Vehicle Design:
  - Increased payload capability through optimized fuel usage
  - Reduced design costs through optimized control effectors
  - Reduced test and checkout costs

  Mission Operations:
  - Reduced preflight targeting cycle duration, simulation activity (30%)
  - Increased mission success under variable conditions (40%)
- Risk:
  - Low to medium schedule and cost
  - Vehicle dynamics must be predictable within established stability limits

QUALITATIVE TECHNOLOGY BENEFIT

- Enhanced robustness for adverse weather operations
- Improved operational readiness/retargeting on pad
- Increased vehicle autonomy, reduced vulnerability
- Improved flexible terminal landing phase operations

QUANTITATIVE BENEFITS ANALYSIS

- IRR: 35%*
- % LCC: <1%*
- Leverage: 21*

*Based on SDI architecture analysis

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MLG102/IPKS

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LOX/HC ENGINE TECHNOLOGY PROGRAM

TECHNOLOGY OVERVIEW

- Description: Develop reusable, low maintenance, low cost booster engines for heavy lift launch vehicles using hydrocarbon propellants affording higher density, improved handling and less environmental pollution.
- Objectives
  - Develop main-combustion chamber for high Pc operation
  - Develop gas-generator for selected HC fuels
  - Reduce high-pressure pump/turbomachinery
  - Reduce costs of high-frequency launch operations
- Approach:
  - Design, develop and evaluate main injector for 4000 PSI gas-generator type engine
  - Determine coking during operating cycle and evaluate options to minimize
  - Determine cost-effective provisions for fuel source(s)
  - Define ground processing impact of hydrocarbon boosters

TECHNOLOGY ASSESSMENT

- State-of-the-Art:
  - Hydrocarbon engine used in Saturn boosters and Apollo program
  - Baseline is Shuttle 109% SSME-35 engine
  - Reusable, low maintenance pumps/turbomachinery components common to LOX/H2 engine
- Application:
  Vehicle Design:
  - Smaller, lighter tanks with higher density fuel
  - Higher payload capability per pound of dry weight
  Ground Operations:
  - Enhanced safety of propellant transportation, handling and storage
  - Smaller vehicle facilitates ground handling
- Risk:
  - Low to medium schedule and cost
  - Coking and high Pc operation is technical challenge
  - Determine cost-effective provisions for fuel source(s)

QUALITATIVE TECHNOLOGY BENEFIT

- Determine ground processing impact of HC boosters
- High density fuel enables smaller vehicle size to facilitate ground handling
- Enhanced safety of propellant transportation, handling and storage
- Lower propellant costs, higher payload capability
- Reduced pollution compared to SRBs on STS

QUANTITATIVE BENEFITS ANALYSIS

- IRR: 9%*
- % LCC: 2%*
- Leverage: 2*

*Based on SDI architecture analysis

MLG122/IPRS

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SUMMARY OF TECHNOLOGY TRENDS AND FINDINGS

- TECHNOLOGY INVESTMENT MAKES SENSE
- APPLICATION OF NEW TECHNOLOGIES IS CRITICAL TO COST-EFFECTIVE ACQUISITION AND OPERATION OF FUTURE TRANSPORTATION SYSTEMS
- AUTOMATED EXPERT SYSTEMS PROBABLY SINGLE MOST IMPORTANT TECHNOLOGY DEVELOPMENT
  - PROVIDES IMPROVED EFFECTIVENESS FOR MANPOWER INTENSIVE TASKS
  - ESSENTIAL TOOL TO SATISFY DEMANDS OF INCREASED LAUNCH RATES
- ADVANCED PROPULSION AND MATERIALS TECHNOLOGIES WILL LOWER INITIAL COSTS AND PROVIDE IMPROVED EFFICIENCY OF RECURRING OPERATIONS
- ADAPTIVE GN&C WITH A HIGH DEGREE OF FAULT TOLERANCE ARE VERY IMPORTANT TO RELIABLE AUTONOMY, ROBUST OPERATIONS, AND RAPID RESPONSE
- MUST START AGRESSIVE TECHNOLOGY DEVELOPMENT PROGRAM WITH LONG-TERM COMMITMENT NOW TO AVOID LOSS OF POTENTIAL SAVINGS AND TECHNOLOGY LEADERSHIP

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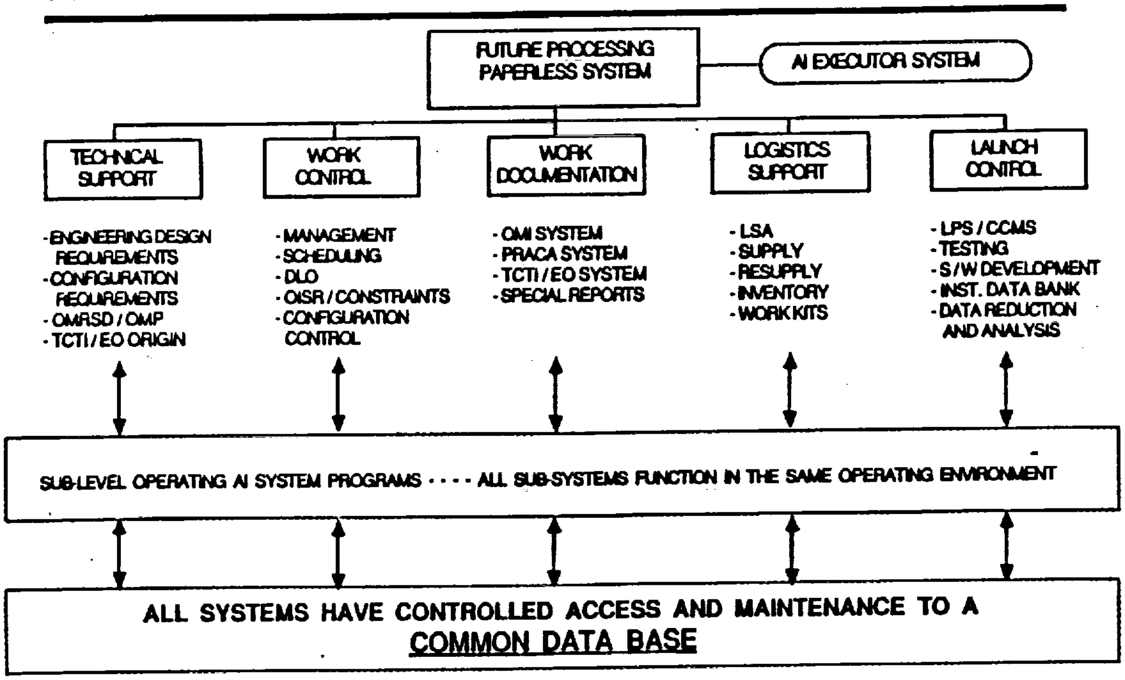
MLG114/IPRS

FUTURE PAPERLESS PROCESSING SYSTEM



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FUTURE PAPERLESS PROCESSING SYSTEM

BENEFITS

- MANAGEMENT CONTROL
  - EXACT SCHEDULE STATUS - - AT ALL TIMES
  - EXACT CONFIGURATION STATUS - - AT ALL TIMES
  - EXACT APPROVAL STATUS OF ALL WADS
  - EXACT STATUS OF ALL LOGISTICS SUPPORT FOR EACH WAD
  - OPTIMUM WORKLOAD PLANNING TO THE TEAM / SHIFT LEVEL

  RESULT IS - BEST PLANNING / SCHEDULING - - > 95% ACCURACY (GOAL)
  - EFFICIENT USE OF MANPOWER POOLS - - > 80% UTILIZATION (GOAL)
- PROCEDURE DOCUMENTATION
  - MORE EFFICIENT GENERATION/ORIGINATION
  - IMMEDIATE/CONCURRENT AVAILABILITY FOR REVIEW/COMMENT/APPROVALS
  - EASIER / QUICKER REVISIONS AND UPDATING
  - MAJOR REDUCTION IN BULK PAPER HANDLING
- PROCEDURE PERFORMANCE
  - MORE EFFICIENT OPERATIONS
  - REDUCTION IN OJT REQUIREMENTS
  - ALLOWS MORE CROSS UTILIZATION OF PERSONNEL
  - MAJOR REDUCTION IN PAPER HANDLING
  - IMPROVED SCHEDULING / RESOURCE UTILIZATION
- MAJOR REDUCTION / ELIMINATION OF STATUS MEETINGS
  - TOP MANAGEMENT WILL HAVE EXACT STATUS FOR DECISION MAKING
  - MEETINGS WILL BE MORE MANAGEMENT / DECISION ORIENTATED

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PROPELLANT COSTS *

PROPELLANT	DELIVERED COST $/LB	REFRIGERATION COST $/LB	BUY-TO-SELL RATIO	TOTAL COST $/LB
LIQUID METHANE (LCH4)	.118	.103	1.1	.243
LIQUID PROPANE (LC3H8) @ N.B.P.	.18	.036	1.1	.24
LIQUID PROPANE (LC3H8) SUB COOLED	.18	.55	1.1	.26
LIQUID OXYGEN (LO2)	.036	N/A	1.8	.063
TURBOJET FUEL	.175	N/A	1.0	.176
LH2	2.0	-	1.2	2.4
A50	6.0	-	.1	6
N2O4	2.75	-	.1	2.75
SOLID	10.0	-	.1	10.0
N2H4	-	-	-	-

* COSTS AS OF OCTOBER 1985

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CDGSTA001.5

(GND OPS SPLINTER 6/19/86)

1.2 Major Findings

Our studies, conducted over the entire STAS contract period, have resulted in the following major findings and conclusions:

- Return mission requirements identified in the Civil Mission Model II are a major driver. Two-thirds of the total mass delivered to orbit requires return from orbit. The annual return mass requirement continually increases throughout the years of the mission model and more than doubles from 1995 to 2010. These return requirements, in conjunction with the limited down-payload capability of the current Shuttle, result in excessive use of the existing Shuttle systems requiring very substantial investment in additional facilities and hardware.

- Significant productivity improvements to current systems are possible. Near-term upgrades via redesigns and procedural operations changes, incorporating available technologies with demonstrated maturity, could afford substantial reduction in recurring operating costs of existing Shuttle and ELV systems (estimated reduction by a factor of 3 to 5 compared to current operating cost levels is possible by mid- to late-1990s).

- Analyses based on National Mission Model definition indicate that early (1995) introduction of a reliable, low-cost, heavy-lift unmanned cargo vehicle is desirable to: 1) relieve dependence on more costly expendable launch vehicles operating above high-frequency launch threshholds; 2) provide required assured access capabilities; and 3) accommodate projected growth in payload weight. Cost/technology analyses resulted in selection of an initially expendable cargo vehicle evolving into increasing reusability as technology development progresses.

- A new manned vehicle is recommended to initially augment and ultimately replace the current Shuttle in the 2005-2010 timeframe. Our recommended Shutle II vehicle design uses the flyback booster developed for our partially reusable cargo vehicle, and incorporates technology enhancements providing lower cost of recurring operations, increased robustness and greater flexibility.

- Results of extensive vehicle sizing trade studies indicate that minimum design capabilities should be 40K-lbs for Shuttle II and 100K-lbs for the unmanned cargo vehicles; these sizes are related through use of the common flyback booster. Both vehicles should be sized to provide a cargo bay clear volume which accommodates 15-ft diameter payloads. There is substantial risk in oversizing these vehicles, both in lift capability and diameter, primarily reflected in degraded manifesting load factors.

- Cost of providing assured access capability is substantial. Several approaches were identified and costed, ranging from ~$9B to ~$15B. The recommended approach retains an improved Titan IV/Centaur in the vehicle inventory throughout the span of the mission model. A flight rate of two vehicles per year per launch site (ETR and WTR) was assumed to maintain ready status.

- Reusable upper stage vehicles for orbit transfer to support geosynchronous, manned lunar or interplanetary mission operations will require significant technology developments; requirements for these systems are not soundly justified in the current mission models.

- Manifesting constraints have a significant effect on architecture cost. The ability to efficiently manifest and then deploy multiple payloads on a large-capability cargo vehicle must be realized to achieve low delivery cost.

- Launch processing facilities are aging; real estate for new builds is limited; and EIS processing/approval is very likely to be on the critical path for future programs.

- Advanced technology applications are mandatory for significant cost reductions. Projected life cycle cost reduction of 40% is attributable to incorporation of advanced technology in the new unmanned partially reusable cargo vehicle, compared to cost of this same vehicle designed with existing technology. Even more impressive is the projected reduction of 50% in recurring costs for this vehicle.

- Introduction of advanced technologies must be judiciously timed to ensure adequate maturity through thorough testing in order to minimize program risk.

- A long-term commitment to an agressive technology development program must be made to avoid loss of potential future savings and inability to confidently select from many viable alternatives before commitment to development of new systems.

- Low cost propulsion systems with reliable low-cost engines, high-density fuels with increased specific impulse, and lightweight tanks all afford opportunities for significant cost savings inherent to designs initiated in the early- to mid-1990s.

- Incorporation of advanced materials with substantially greater thermal tolerance and reduced density could provide significant reduction in vehicle dry weight and postflight operations for vehicles to be introduced beyond the turn of the century.

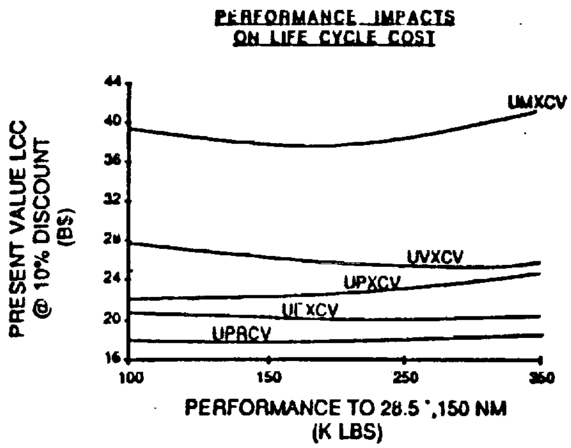
- Economic analysis is a good measure for focusing technology and design options, but it must be supplemented with broad experience and knowledge to define key technologies required to maintain world leadership.

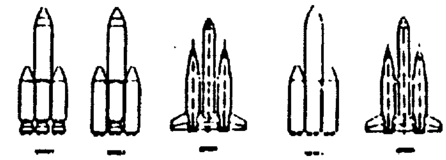
- Not all requirements can be justified solely on the basis of Life Cycle Cost analyses, since more aggressive mission options have not been sufficiently identified or addressed (i.e., high energy orbit activities, lunar or Mars excursions, etc.).

- All guiding principles must be fully considered in final architecture selection and technology planning. The mission model by itself does not drive all requirements for robustness and flexibility.

- Management culture shock may be an intrinsic element in the price of progress; new ways of doing business must be reviewed and received with open minds.

VEHICLE SELECTION





UMXCV - 1st Stage P/A, 2nd Stage P/A

UVXCV - Exp. With 2nd Stage P/A

UPXCV - Fly Back Booster, 2nd Stage P/A

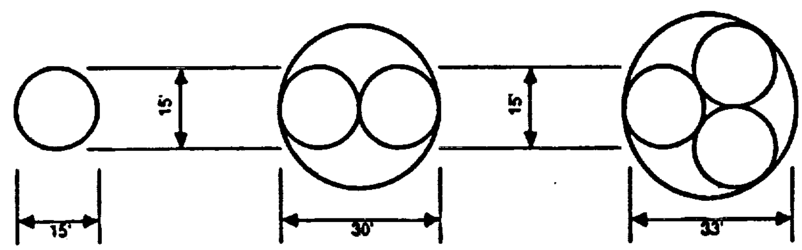
UEXCV - New All Expendable

UPRCV - Fly Back Booster, 2nd Stage Exp.

MOST COST EFFECTIVE NEW SYSTEM HAS FLYBACK BOOSTER

CARGO VEHICLE SIZING CONSIDERATIONS

- MOST PAYLOADS ARE 15-FT DIAMETER (OR LESS)
- PAYLOADS EXCEEDING 15-FT DIAMETER ARE MODULARIZABLE
- DUAL COMPATIBILITY WITH SHUTTLE AND TITAN IS REQUIRED
- PAYLOADS SHOULD NOT BE DRIVEN TO EXCEED 15-FT DIAMETER
- CARGO BAY MUST EFFICIENTLY ACCOMMODATE 15-FT DIAMETER PAYLOADS



DEDICATED CARRIER (15' DIA) | DOUBLE CARRIER (30' DIA) | TRIPLE CARRIER (33' DIA)

SUMMARY OF TRENDS/FINDINGS

- RETURN MISSION REQUIREMENTS ARE MAJOR DRIVER
- ADVANCED TECHNOLOGY APPLICATIONS REQUIRED FOR COST REDUCTION
- ASSURED ACCESS IS EXTREMELY COSTLY
- CARGO VEHICLE PAYLOAD ACCOMMODATION SHOULD BE 15' DIAMETER
- MANIFESTING CONSTRAINTS REPRESENT A MAJOR COST DRIVER
- STS COSTS MUST BE REDUCED TO ALLOW NEW SYSTEM DEVELOPMENT
- SIGNIFICANT UP-FRONT INVESTMENT REQUIRED FOR SUBSTANTIAL RECURRING COST REDUCTIONS

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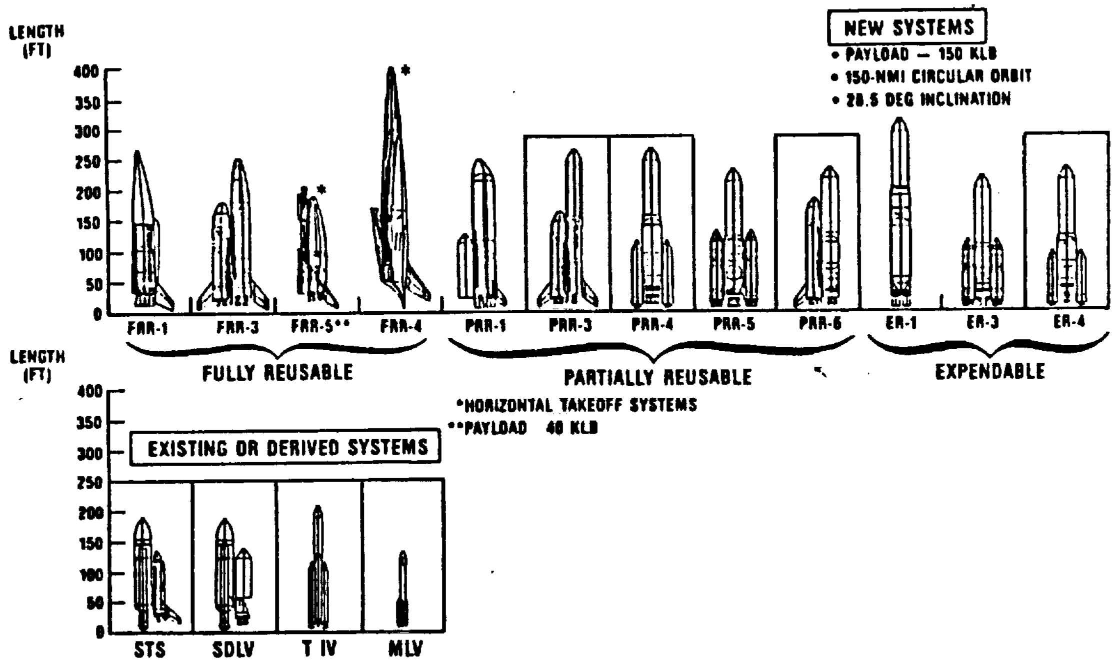
6.8.4 ROCKWELL STAS

A Full Range of Launch Vehicles Was Considered



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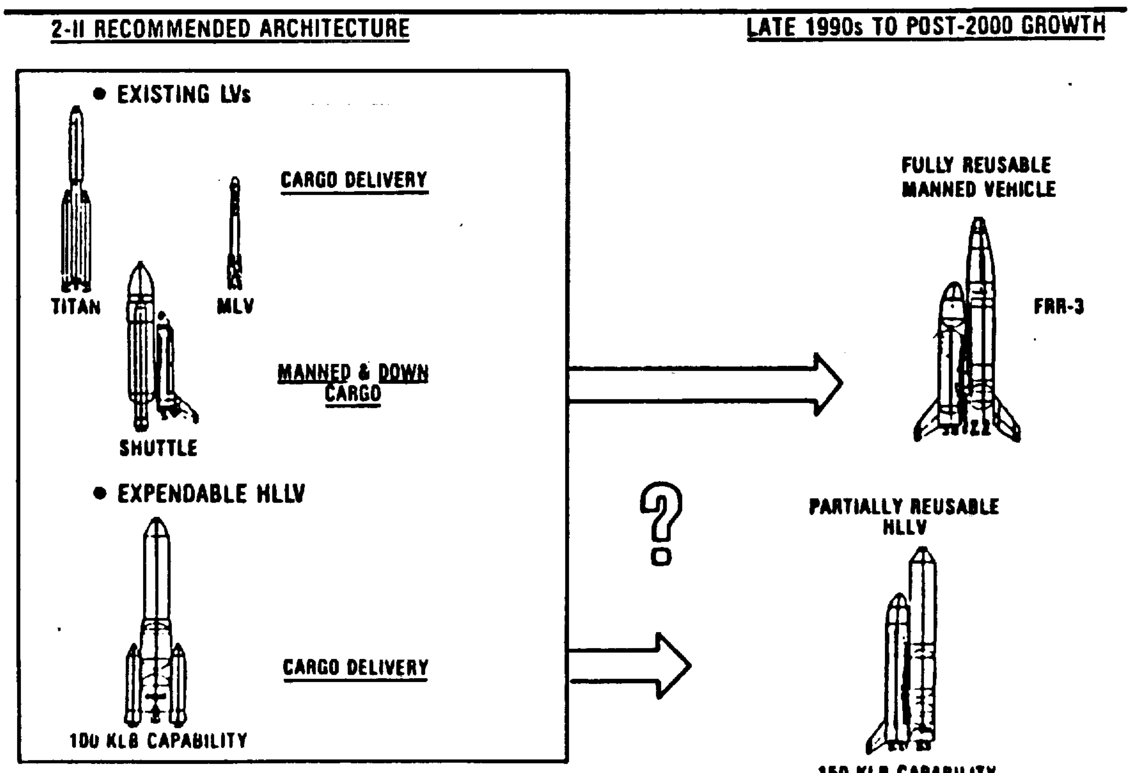
Launch Vehicle Architecture Allows Growth to Meet Potential Future Needs



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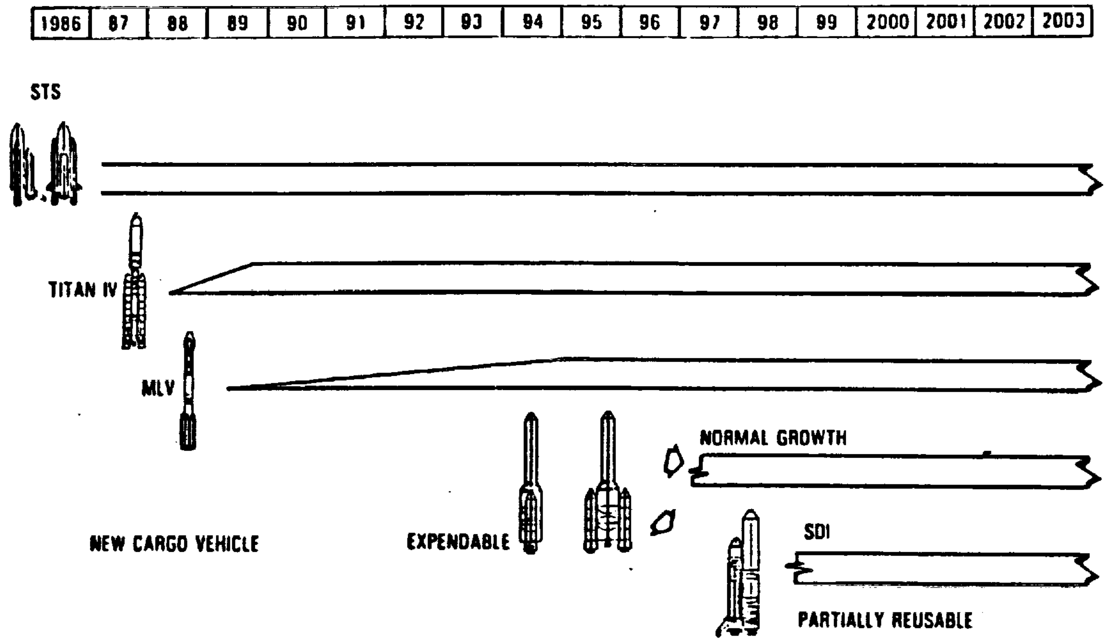
Launch Systems for Recommended Architectures



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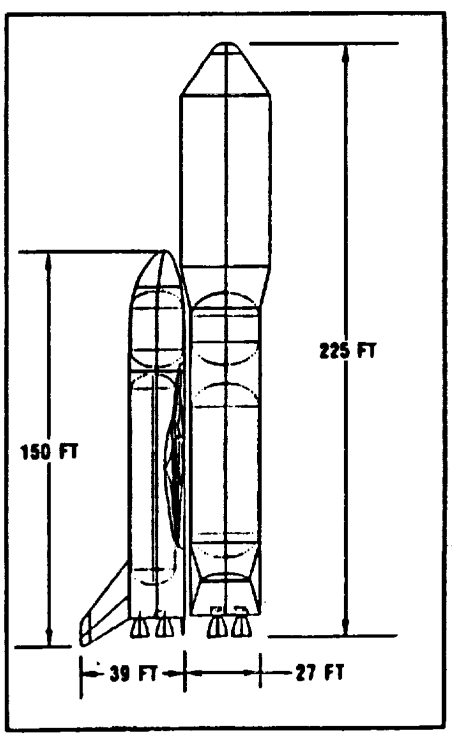
Partially Reusable Launch Vehicle Characteristics



- ROCKWELL DESIGNATOR: PRR-6
- DESIGN FEATURES
  - REUSABLE FIRST STAGE
    - CRUISEBACK TO LAUNCH SITE
    - LO_2/LC_3H_8 PROPELLANTS
    - NO CROSSFEED TO EXPENDABLE TANK
    - AlLi TANKAGE/STRUCTURE
    - 4 ENGINES AT 690 KLB THRUST (SL)
  - REUSABLE P/A MODULE
    - SEMI-BALLISTIC RETURN
    - PARACHUTE OR PARAFOIL RECOVERY
    - AlLi STRUCTURE
    - ACC/SIC BLANKET TPS
    - 3 ENGINES AT 280 KLB THRUST (VAC)
  - EXPENDABLE TANK & SHROUD
    - AlLi TANK/STRUCTURE
    - LO_2/LH_2 PROPELLANTS
    - 33 FT X 65 FT SHROUD
- MASS CHARACTERISTICS
  - GROSS: 2,550 KLB
  - PROPELLANT: 2,194 KLB
  - INERT: 191 KLB
  - SHROUD: 15 KLB
  - PAYLOAD: 150 KLB

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6.8.4 ROCKWELL

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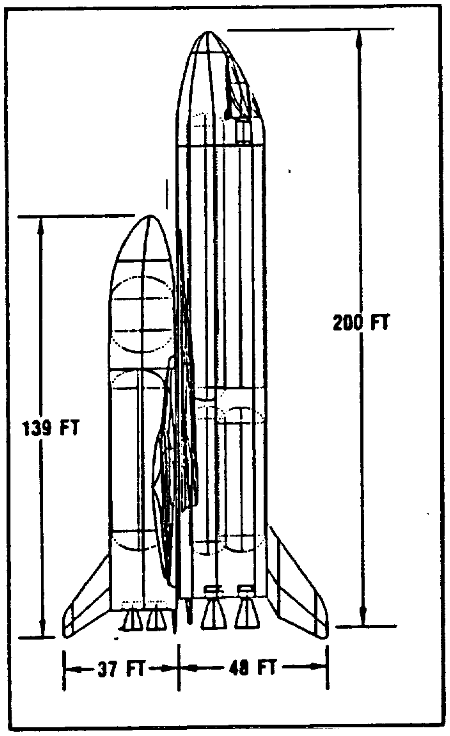
Fully Reusable Launch Vehicle Characteristics



- ROCKWELL DESIGNATOR: FRR-3
- DESIGN FEATURES
  - REUSABLE FIRST STAGE
    - CRUISE BACK TO LAUNCH SITE
    - LO_2/LC_3H_8 PROPELLANTS
    - NO CROSSFEED TO SECOND STAGE
    - ALLI TANKAGE/STRUCTURE
    - 4 ENGINES AT 730 KLB THRUST (SL)
  - REUSABLE SECOND STAGE
    - GLIDEBACK TO LAUNCH SITE
    - LO_2/LH_2 PROPELLANTS
    - ALLI TANKAGE/STRUCTURE
    - 3 ENGINES AT 300 KLB THRUST (VAC)
    - ACC/SiC BLANKET TPS
- MASS CHARACTERISTICS
  - GROSS: 2,707 KLB
  - PROPELLANT: 2,347 KLB
  - INERT: 280 KLB
  - PAYLOAD (15 FT X 80 FT): 80 KLB

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ER-4 Vehicle Processing Activities — Shifts and Manpower

ACTIVITIES	NUMBER OF SHIFTS PER ACTIVITY	NUMBER OF PERSONNEL PER SHIFT	MAN-SHIFT	TOTAL MAN-HOURS
P/A PROCESSING & C/O	27	120	3,240	25,920
CORE PROCESSING	24	60	1,440	11,520
P/A — CORE MATE	9	70	630	5,040
SRB BUILDUP	40	40	1,600	12,800
SRB ASSEMBLY	4	40	160	1,280
SRB STACK	15	40	600	4,800
SRB-CORE MATE	3	40	120	960
SRB-CORE CLOSEOUT	15	40	600	4,800
PAYLOAD CHECKOUT	18	70	1,260	10,080
SHROUD PREPARATION	6	10	60	480
PAYLOAD-SHROUD MATE	3	25	75	600
SHROUD-CORE MATE	3	40	120	960
PAD OPERATIONS	21	80	1,680	13,440
PAD REFURBISHMENT	12	90	1,080	8,640
MLP REFURBISHMENT	9	70	630	5,040
TOTALS	245	835	13,295	106,360

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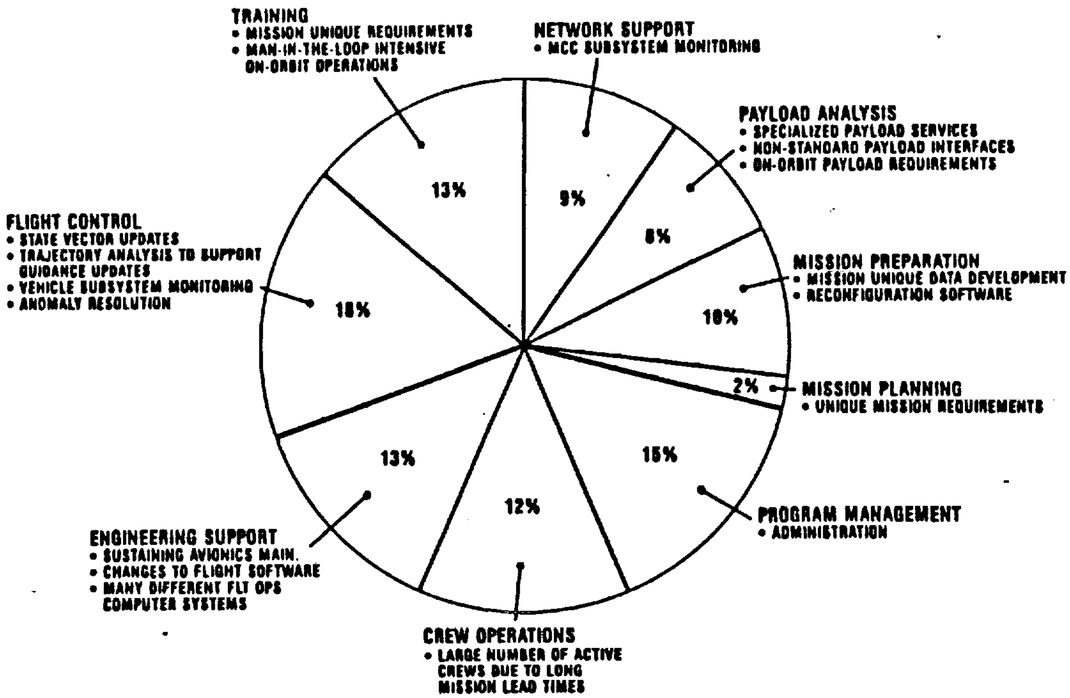
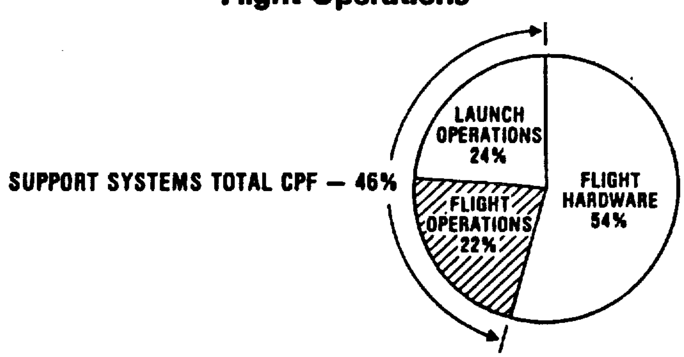
Flight Operations Costs Are Dominated by Mission-Related Activities



Support Systems Presently Comprise Large Portion of Flight Costs

Flight Operations



OPTIONS LEADING TO LOW FLIGHT OPERATIONS COSTS:

- STANDARDIZED PAYLOAD INTERFACES
- SCHEDULED FLIGHTS
- VEHICLE AUTONOMY
- STANDARDIZE SOFTWARE
- FLIGHT BOOKING

AUTO BOOKING

Near-Term Launch Vehicle System Utilizes Focused Current Technology

FUNCTION/ELEMENT	TECHNOLOGY	BENEFIT
CORE		
• TANK STRUCTURE	Al Li MATERIAL ISOGRID	IMPROVED PERFORMANCE REDUCED ASSEMBLY LABOR
• PROPULSION		
• ENGINE	EXPENDABLE LO_2/LH_2	LOWER COST
• RCS	GASEOUS LO_2/LH_2	REDUCED COMPLEXITY
• TVC	ENGINE GIMBAL POWER	ELIMINATE APU
BOOSTER		
• TANK STRUCTURE	FILAMENT WOUND	IMPROVED PERFORMANCE SIZE ADAPTABLE
• PROPULSION		
• MOTOR	IMRPOVED SOLID PROPELLANTS	UPRATED PERFORMANCE REDUCED CONTAMINENTS
AVIONICS		
• GN&C	AUTON ONBOARD EXPERT	MISSION COMPLETION
• HEALTH MONITORING	AUTO MALFUNCTION PROCEDURE	MISSION COMPLETION
• CHECKOUT	AUTO SELF-CHECKOUT	FASTER RESPONSIVENESS LOWER LAUNCH COST
MANUFACTURING		
• FABRICATION	COMPUTER INTEGRATED MFG	REDUCED COST
• ASSEMBLY	ROBOTICS	REDUCED COST
• ACCEPTANCE C/O	AUTOMATED PROCEDURES	IMPROVED RELIABILITY

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Growth Systems Utilize Advanced Technology - Partially Reusable Systems

FUNCTION/ELEMENT	TECHNOLOGY	BENEFIT
CORE		
• TANK STRUCTURE	SIC/Al MATERIAL ISOGRID	IMPROVED PERFORMANCE REDUCED ASSEMBLY LABOR
P/A MODULE		
• PROPULSION		
• MAIN ENGINES	ADV REUSABLE LO_2/LH_2	REDUCED MAINTENANCE
• RCS	GASEOUS LO_2/LH_2	REDUCED COMPLEXITY
• TVC	ENGINE GIMBAL POWER	ELIMINATE APU
• RECOVERY		
• TPS	ADV FIBER BLANKET TPS	REDUCED MAINTENANCE
• LANDING	ADV RECOVERY SYSTEMS	IMPROVED RELIABILITY
FLYBACK BOOSTER		
• FUSELAGE STRUCTURE	HIGH-TEMP Al ALLOYS ISOGRID	TPS ELIMINATED REDUCED ASSEMBLY LABOR
• PROPULSION		
• MAIN ENGINES	ADV REUSABLE LO_2/LHC	REDUCED MAINTENANCE
• RCS	GASEOUS LO_2/LH_2	REDUCED COMPLEXITY
• TVC	ENGINE GIMBAL POWER	ELIMINATE APU
AVIONICS		
• GN&C	AUTON ONBOARD EXPERT	MISSION COMPLETION
• HEALTH MONITORING	AUTO MALFUNCTION PROCEDURE	MISSION COMPLETION
• CHECKOUT	AUTO SELF-CHECKOUT	FASTER RESPONSIVENESS LOWER LAUNCH COST
POWER SUPPLY		
• GENERATION	HI-POWER-DEN FUEL CELLS	REDUCED WEIGHT LOWER COST
MANUFACTURING		
• FABRICATION	COMPUTER INTEGRATED MFG	REDUCED COST
• ASSEMBLY	ROBOTICS	REDUCED COST
• ACCEPTANCE C/O	AUTOMATED PROCEDURES	IMPROVED RELIABILITY

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Growth Systems Utilize Advanced Technology—Advanced Manned Systems

FUNCTION/ELEMENT	TECHNOLOGY	BENEFIT
ORBITER		
• FUSELAGE		
• STRUCTURE	SIC/AI ALLOYS OR SIC FOAM SANDWICH	IMPROVED PERFORMANCE & HIGHER ALLOWED TEMPS
• TPS	HARDENED TPS	ELIMINATED MAINTENANCE
	ADV RCC	EROSION PROTECTED
	ADV FIBER BLANKET	ALL WEATHER OPERATION
• PROPULSION		
• MAIN ENGINES	ADV REUSABLE LO_2/LH_2	REDUCED MAINTENANCE
• RCS	GASEOUS LO_2/LH_2	REDUCED COMPLEXITY
• TVC	ENGINE GIMBAL POWER	ELIMINATE APU
FLYBACK BOOSTER		
• FUSELAGE STRUCTURE	HIGH-TEMP AI ALLOYS ISOGRID	TPS ELIMINATED REDUCED ASSEMBLY LABOR
• PROPULSION		
• ENGINE	ADV REUSABLE LO_2/LHC	REDUCED MAINTENANCE
• RCS	GASEOUS LO_2/LH_2	REDUCED COMPLEXITY
• TVC	ENGINE GIMBAL POWER	ELIMINATE APU
AVIONICS		
• GN&C	AUTON ONBOARD EXPERT	MISSION COMPLETION
• HEALTH MONITORING	AUTO MALFUNCTION PROCEDURE	MISSION COMPLETION
• CHECKOUT	AUTO SELF-CHECKOUT	FASTER RESPONSIVENESS, LOWER LAUNCH COST
POWER SUPPLY		
• GENERATION	HI-POWER-DEN FUEL CELLS	REDUCED WEIGHT, LOWER COST
MANUFACTURING		
• FABRICATION	COMPUTER INTEGRATED MFG	REDUCED COST
• ASSEMBLY	ROBOTICS	REDUCED COST
• ACCEPTANCE C/O	AUTOMATED PROCEDURES	IMPROVED RELIABILITY

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Improved Operations Support Results From Todays Technology

FUNCTION/ELEMENT	TECHNOLOGY	BENEFIT
GROUND PROCESSING		
• PAYLOAD PROCESSING	CONTAINERIZATION	REDUCED VEHICLE CLEANLINESS
	AUTOMATED CHECKOUT	FASTER PROCESSING
	AUTO MALFUNCTION PROCEDURE	RAPID C/O
• VEHICLE ASSEMBLY	ROBOTIC MACROPROCESSING	REDUCED COST
	AUTO MALFUNCTION PROCEDURE	RAPID C/O
• CHECKOUT	AUTOMATED CHECKOUT	RAPID C/O
	AUTO MALFUNCTION PROCEDURE	RAPID C/O
	SMART SENSORS FOR ROBOTICS	REDUCED COST
• LAUNCH	LAUNCH CONTROL EXPERT	INCREASED RESPONSE
MISSION CONTROL		
• MISSION PLANNING		
• FLIGHT BOOKING	STANDARDIZATION	REDUCED COST
• FLIGHT KIT DEVEL	SOFTWARE PROD & MAINT RAPID PROTOTYPING	INCREASED RELIABILITY REDUCED COST
• SIMULATION	SOFTWARE ENGINEERING	IMPROVED PERFORMANCE
• FLIGHT CONTROL		
• CONTROLLER	AUTON MISSION CONT EXPERT	REDUCED COST
• WORK STATIONS	INTELLIGENT STATIONS	GREATER UTILITY RAPID RECONFIGURATION
• NETWORK		
• COMMUNICATIONS	FIBER OPTICS	INCREASED DATA RELIABILITY

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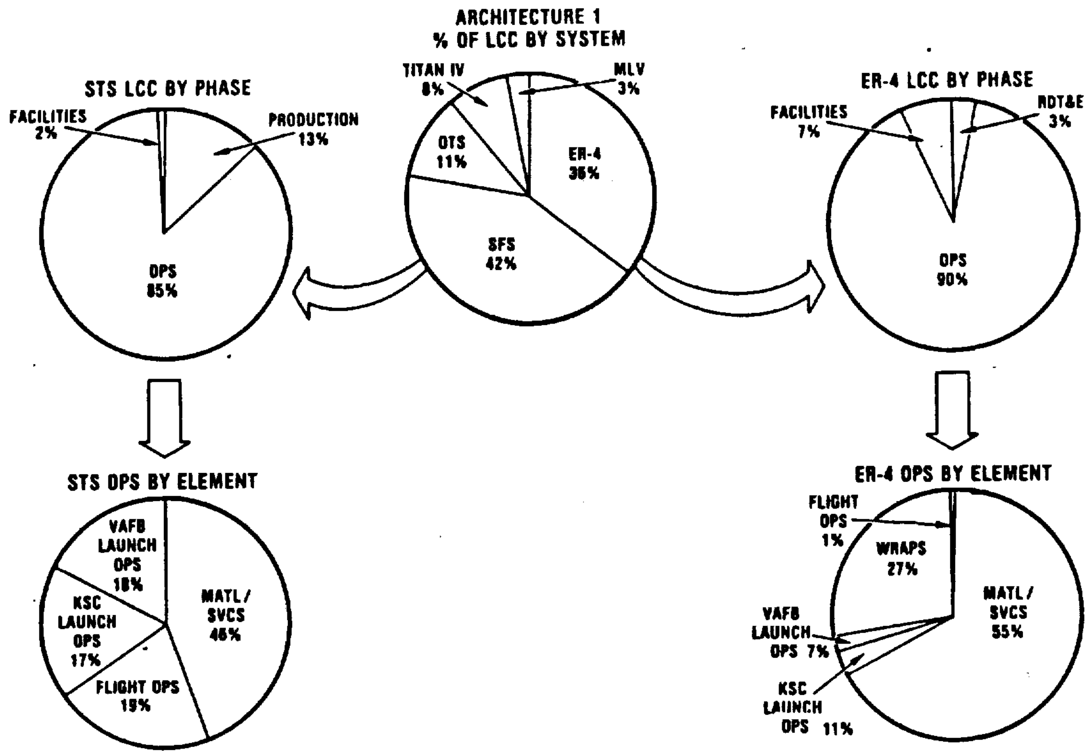
Major Cost Contributors



Forecasted Costs for Assessed Technologies

TECHNOLOGY No.	Name	1987	1988	1989	1990	1991	1992	1993	1994	1995	TOTAL
AI/EXPERT SYSTEMS											
2	Autonomous, On-board Mission Control Expert										
3	Launch Control Expert										
4	Vehicle Ground Expert Processing Planner	11.5	15.0	16.0	10.5	3.0	1.0				57.0
5	Automated Malfunction Procedure & Safing										
6	Automated Self-Checkout										
SOFTWARE PRODUCTION AND MAINTENANCE											
8	Software Production & Maintenance Methods										
9	Software Engineering Environment	Commercial Development Expected									
10	Software Languages										
11	Rapid Prototyping										
12	AI in Software Engineering	8.0	6.0	7.0	7.0	6.0	6.0	5.0	4.0		49.0
13	Software Metrics and Measurement	6.0	6.0	6.0	7.0	5.0	4.0	3.0	3.0		40.0
ROBOTICS AND AUTOMATION											
18	Robotic Macroprocessing	1.4	3.4	5.4	3.6	0.4					14.2
20	Smart Sensors for Robotics and Automation	1.4	1.4	2.6	3.4	3.2	1.8	1.0	0.4		15.2
											0.0
OPERATIONS											
22	Adverse Weather Protection and Operations		TBD								

Conclusions

ARCHITECTURE

- OTV — EXISTING STAGES CAN ACCOMPLISH ALL OF THE MISSIONS
  - ASSURED ACCESS REQUIRES A NEW UPPER STAGE WITH 12.5KLB GEO DELIVERY CAPABILITY
- LAUNCH VEHICLE
  - UNMANNED CARGO VEHICLE NEEDED BY MID 1990s
    - EXPENDABLE FOR NOMINAL MODEL
    - PARTIALLY REUSABLE NEEDED FOR KEW SCENARIO
  - MANNED MISSIONS ACCOMPLISHED WITH SHUTTLE
    - NEED BASELINE RETURN CARGO CAPABILITY
    - NEED TO EXAMINE ALTERNATES FOR MANNED & RETURN CARGO BACKUPS

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Recommendations

- START DEFINITION & MOVE TOWARD DEVELOPMENT OF EXPENDABLE HLLV
  - PLAN NOW FOR ULTIMATE PARTIALLY REUSABLE SYSTEM TO SUPPORT LATE 1990s GROWTH/LOWER OPERATIONS COST
  - INITIAL STEP/ULTIMATE STEP CONNECT
- CONTINUE AGGRESSIVE TECHNOLOGY PROGRAM
  - SUPPORTS MORE REUSABLE CARGO & MANNED VEHICLE DECISIONS
  - FOCUS CURRENT TECHNOLOGY FOR LOW COST MANUFACTURING & OPERATIONS

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6.8.5 STAS GROUNDRULES

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9.1 GROUNDRULES AND ASSUMPTIONS

This appendix contains the major Government provided and contractor derived groundrules and assumptions for STAS.

The groundrules are characterized under the major study areas for clarity. However, many groundrules impact areas other than the primary area under which they are listed.

9.1.1 GOVERNMENT SUPPLIED GROUNDRULES. The following STAS groundrules were provided by NASA MSFC 20 February 1987.

ARCHITECTURE GROUNDRULES AND ASSUMPTIONS.

A-1 Viable architecture will be based on a mixed fleet concept for operational flexibility. As a minimum, two independent (different major subsystems) launch, upper stage, and return to earth (especially for manned missions) systems must be employed to provide assured access for the specific, high priority payloads designated in the mission model.

A-2 A viable architecture must capture 100% of the missions in the model option for which it is synthesized. Requirements for large, driver-type payloads which fly on an infrequent basis should not be allowed to exert inordinate influence on the architecture. Drivers shall be identified for government concurrence.

A-3 All elements, equipment, and operations associated with any OTVs must be included in the architecture costs. IOC for OTVs (ground or space-based) is to be determined by analysis.

A-4 A minimum of 3 years (elapsed time) must be allowed to ramp up a new system to full operations (steady state) to provide a smooth transition between existing and new architectures (facilities, systems, equipment and operations).

A-5 Assume the following systems exist in 1995: 4 orbiter space transportation fleet with launch facilities at ETR and WTR whose total launch capability is 16/yr; Titan IV at ETR and WTR; a new medium ELV at ETR; PAM, IUS, and Centaur G' upper stages; and an unmanned OMV (one each, ground and space station based).

A-6 Reserve for future use.

A-7 Use government furnished Shuttle and Titan IV cost data (STAS input).

- Extrapolate to higher flight rates
- Assume maximum of 6 launches/year from existing Titan IV (TIV) pat at WTR

A-8 For reusable vehicles (or reusable elements of vehicles) the number that must be in the active inventory in any year must be one greater than the number necessary to support the number of flights in that year.

MISSION CAPTURE AND MANIFESTING GROUNDRULES AND ASSUMPTIONS

C-1 All delivery and return payloads and/or upper stages must be accounted for in the manifesting. Specific manifesting should include the following considerations:

- Launch vehicle and OTV type
- Payloads or payload groupings
- Destination and launch site
- Delivery weight and volume/length
- Retrieval weight and volume/length
- Delivery propellants required (for upper stages)

C-2 Payloads shall be launched during the calendar year specified in the mission model.

C-3 Weight and dimensional constraints must be observed for payloads of 1000 lbs. or more and for upper stages on launch vehicles (both deploy and return missions).

C-4 Escape payloads, (i.e., planetary, lunar, etc.) must be dedicated upper stage flights.

C-5 Co-manifesting of payloads should follow the designated rule for each payload in the mission models. Rules designated for the specific payloads are:

1) Must be flown alone.
2) May be flown with other like payloads.
3) If a DoD payload, it may be flown with other DoD payloads. If a civil or foreign payload, it may be flown with other civil or foreign payloads.
4) May be flown with any other payload. (Default, if no designation).
5) May not be flown with other like payloads.

C-6 Payloads in the Civil Mission Model may be modularized. For the DoD mission model, assume no payload modularity, unless for the purposes of trade studies or as otherwise directed.

C-7 DoD payloads may not be processed at the Space Station unless on orbit facilities and mission control functions have been designated and costs have been estimated to include secure operational capabilities.

C-8 Differing ascending nodes must be accounted for in multiple-plane constellations. Assume planes are equally spaced if not otherwise specified in the mission model.

C-9 Very small payloads (under 1000 lbs.) to the same orbit can be combined into palletized packages up to 5000 lbs. A weight equal to 15% of the payload weight and appropriate dimensions shall be assumed for the pallet (includes ASE and mounting weight).

C-10 STS Flights to the space station require a docking module.

- Docking module weight is 3500 lbs.
- Docking module length is 7 ft.

C-11 In cargo bay dedicated tanker, mass fraction is 0.90

C-12 Low earth orbit transportation system mission duration is both vehicle and mission dependent. If design/mission specific values are not generated, nominal assumptions for fully or partially reusable systems should be:

- Delivery mission: 2 Days
- On-orbit support missions: 7 days
- Manned retrieval missions: 4 days

C-13 Reserved for future use.

C-14 ASE weight is assumed to be 15% of the total payload and loaded OTV weight (including attach/support structure, Groundrule C-15), or 15% of the total payload weight where no OTV is required.

C-15 A factor of 10% of payload weight (not including the OTV) is to be added to payloads on an OTV to account for attach/support structure between the OTV and payload.

C-16 Reserved for future use.

C-17 For cryogenic, space based, orbit transfer systems, a 1.075 propellant handling factor must be assumed to account for fuel losses.

C-18 The following manifesting constraints should be used unless the contractor submits justification for specific exceptions. These consolidated manifesting groundrules should be used to account for the impact of real world integration complexities. They should be applied above and beyond the weight and dimensional manifesting constraints.

	MINIMUM % OF A LAUNCH (4) VEHICLE FLIGHT REQUIRED
PAYLOAD w/UPPER STAGE FLIGHTS (2)	
LARGE UPPER STAGE FLIGHT	50%
SMALL UPPER STAGE FLIGHT	25%
PAYLOAD ONLY FLIGHTS (3)	
> 20 KLB PAYLOAD	25%
>5 KLB & <20 KLB PAYLOAD	15%
<5 KLB PAYLOAD	10%

(1) Neither ASE weight nor payload/upper stage integration weight is to be included when categorizing missions.

(2) Upper stage flights:

- Large upper stage flights are those that deliver >5klbs. payload equivalent to GEO (e.g. IUS, Centaur DI, DIT, and TOS).
- Small upper stage flights are those that deliver >5klbs. payload equivalent to GEO (e.g. PAM series).
- No more than two payloads may be manifested per upper stage.

(3) Payload only flights:

- A pallet containing a number of small payloads is equivalent to a single 5klb. - 20 klb. payload.
- Payload weights include any kick stages and integral propulsion.

(4) Larger numbers of like payloads may be manifested on launch vehicles and upper stages if off-line integration in a payload canister is assumed and justified (e.g. SDIO multiple satellite missions).

VEHICLE DESIGN/PERFORMANCE/SIZING GROUNDRULES AND ASSUMPTIONS

V-1 Flight performance reserve (FPR):

- Launch vehicle FPR shall be 1% of the total launch vehicle characteristic velocity and be additive to the final stage.
- On-orbit stage FPR shall be equal to 2% on each delta-velocity maneuver; reflected as main engine propellant reserve at mission completion.

V-2 Launch vehicle reference performance (cargo weight capability) is to be quoted to 150 and 220 nmi/28.5 degrees and 150 nmi 90 degrees circular orbits.

V-3 Reusable launch system orbiter elements shall be sized for delivery of payloads to a 150 nmi circular orbit and 250 fps delta-velocity from the RCS (for both attitude control and maneuvering). Contractor will additionally identify P/L penalty incurred if destination is Space Station orbit rather than 150 nmi circular.

V-4 New transportation system earth orbit hardware (excluding satellites) must include capability for disposal so that they no longer pose a hazard to operational satellites.

V-5 A dry weight contingency will be included on space transportation systems to reflect development status, technology, and design complexity. These contingencies are as follows:

- 5% on existing hardware or modified existing hardware
- 15% on new hardware using current technology or normal expected technology improvements
- 25% on new hardware using advanced technologies

V-6 Designs of proposed new vehicles and derivative systems shall incorporate the following characteristics:

- Checkout, launch, landing/recovery shall not be unduly constrained by weather.
- Failure of a single system/subsystem shall not result in an unsafe condition or delay the countdown or launch.
- Elements shall be easily transportable to and around the launch site by conventional methods (road, rail, air, water).
- Requirements for heating, cooling, purges, insulation, and environmentally-

controlled storage shall be minimized.

- Reusable elements shall nominally be recovered at the launch site; contingency landing considerations shall not require development of special sites.
- Electrical interconnections and mechanical attachments between elements and subsystems, the launch vehicle and ground systems and the launch vehicle and its cargo/payloads shall be standardized and minimized, and replaceable units shall be readily accessible.
- Use of hydraulic systems for flight elements shall be avoided.
- Capability for automated servicing should be provided.
- Use of disparate propellants/fluids should be minimized.
- Accommodations for payloads/cargos shall be designed for ease of installation, interface verification and removal
- Thermal protection system shall be durable, reusable, and easy to install, inspect and repair/replace.
- All elements arrive at launch site fully assembled, checked out and ready for integration with other elements.
- Maximize capability for onboard checkout/fault isolation, and minimize requirements for redundant testing and routine maintenance, refurbishment and inspection.

ADDITIONAL DATA FROM NASA JSC (CT/2-10-87)
STS Capability for Advanced Planning (OV 103)

	ETR	WTR
UP CAPABILITY		
CETF Reference	40530	16500
220 nm – 150 m,	+7000 47530	
140 nm – 150 nm		–1000 15500
7 crew – 5	+900 48430	+900 16400
4 cryos – 3	+1350 49780	included 16400
Off Load Cryo	+400 50180	+400 16800
Off Load Fwd RCS	620 50800	
DOWN CAPABILITY		
– Abort	50800	(ref Memo TM3-86-051)
– Nominal	22750	(ref CETF Report)

Note: Specific missions may require addition/deletion of various options and must be assessed on a mission by mission basis.

GROUND OPERATIONS/LOGISTICS/SUPPORT GROUNDRULES AND ASSUMPTIONS

G-1 Inclination/launch azimuth capabilities and restrictions for new launch sites shall be defined by the contractor. Facility siting shall conform with existing safety and environmental requirements. Any deviation from present range safety restrictions and/or siting constraints will be identified and justified.

G-2 Processing facilities and operations shall have the capability to process and launch secure DoD payloads.

G-3 Facilities, launch pad configurations, procedures and equipment shall be designed for maximum interchange at each launch site to the extent economically and operationally practical.

G-4 Facilities construction is required to be completed no later than two years prior to IOC of the first vehicle. Launch site support equipment installation is required to be completed no later than one year prior to IOC of the first vehicle.

G-5 Critical path operations shall be scheduled and cost shall be estimated on the basis of a five day, three shift work week with selected exceptions to accommodate hazardous operations or operations inherently requiring continuous effort until completed. Non-critical path operations shall be scheduled for cost effectiveness (accounting for facility and equipment costs), but at no more than 5/3 shifting. Operations manhours required shall be defined and manpower costs estimated at a standard rate of $25/hour for direct and indirect labor. For VAFB, a rate of $30/hour shall be used. These rates include profit, but do not include other government wraparounds.

G-6 For new systems assume no payload changeout at the launch pad, except for the purposes of trades. Payload/LV mating for the new vehicle systems shall occur no earlier than 120 hours before launch.

G-7 Facilities and equipment shall be designed to accommodate a surge factor of 40% over the nominal launch rate to provide flexibility in recovering from launch delays and/or anomalies.

G-8 Launch pads and integration facilities shall be sited to accommodate future vehicle growth of 100% in GLOW, or to a maximum payload capability of 500,000 lb to LEO whichever is smaller.

G-9 Facilities and equipment design and location shall not allow a single on-pad catastrophic event to cause long-term disruption (e.g. greater than sixty days) of operations. Non-redundant elements which are essential to vehicle processing may be utilized if justified.

G-10 Reserved for future use.

G-11 Special tests (tanking, FRR, Acceptance, Design Verification, etc.) shall be performed prior to arrival at the launch site.

G-12 Contractor may assume operational environment safety requirements will be standardized between agencies.

G-13 Successful mission on last flight substantially proves readiness for next flight. Preflight checkout requirements shall be minimized by use of on-board systems status checks.

G-14 In the event that turnaround analyses indicate processing flows which exceed current capabilities, requirements for new facilities to support these flows should be identifed and ROM costs provided.

G-15 When the launch rate exceeds STS, ELV, or upper stage facility support capability, requirements for new facilities should be identified and ROM costs provided.

G-16 When constructing timelines for use in STS turnaround analyses, use post 51-L planning (60 day turnaround) to be supplied by KSC.

MISSION CONTROL/FLIGHT OPERATIONS GROUNDRULES AND ASSUMPTIONS

M-1 The Mission Control/Flight Operations will incorporate standardized payload services and interfaces, e.g., standard data bus interface, standard data downlink/uplink communications, and standard flight designs/plans. Payload services will be constrained during ascent or deorbit except for caution and warnings. Standard services for delivery missions will be limited to deployment on-orbit. Additionally, the transportation architecture and Mission Control/Flight Operations will provide for standard servicing missions (probably separate and distinct from deployment missions), i.e., standard payload servicing and routine repair or retrieval/return for repair.

M-2 Facilities and equipment will be designed for a minimum of 25 years and 10 years service life, respectively, and sized for 25% excess throughput capacity over peak mission model requirements.

M-3 Mission control facilities shall have the capability to plan and control secure DoD missions.

M-4 Assume GPS and TDRSS are fully operational for shared use (at a user cost) by 1995. Other navigation and/or communication aids required for operations/control of the architecture must be defined and their cost included in the architecture.

M-5 Assume the basic space station crew and equipment can provide its own mission control support, including one shuttle equivalent resupply mission and two OMV space station support missions per month. Systems equipment, habitat and crew necessary for such activities as cargo handling, OTV support, transportation element operations, etc., beyond these limits must be defined and their cost included in the architecture.

M-6 Sufficient redundancy is required in the overall mission control segment to allow completion of in-progress flights in the face of local catastrophes. (e.g. Return of manned vehicle flights, non-hazardous termination of unmanned vehicle flights).

M-7 MCS embedded computer shall have 100% margin (memory and throughput). This margin for embedded computers is beyond the 25% excess in system capacity (Groundrule M-2).

M-8 The operational TDRSS will consist of four relay satellites with a total of six operational SA links, 20 MA return links, and 4 MA forward links.

M-9 For servicing missions, the actual servicing functions performed after the servicer is at the desired location, are considered payload functions whose control is not provided by the transportation element.

M-10 Facility construction/modification is required to be completed one-year prior to training, simulation, or operation IOC dates. Mission Control/Flight Operations systems support for integrated simulations are to be completed one year prior to IOC of the first vehicle. Training support is required two years prior to IOC of the first vehicle.

TECHNOLOGY GROUNDRULES AND ASSUMPTIONS

T-1 When estimating technology costs and funding schedules, assume the technology plan is fully funded. Do not limit funding for a technology plan because of budget constraints. For technologies, that are already being funded, only include the costs of work that is focused toward future space transportation system needs or those costs associated with modifying or adapting that work.

PROGRAMMATICS/COST GROUNDRULES AND ASSUMPTIONS

P-1 1986 present value of cost streams (estimated in 1986 constant dollars) will be determined for 5% discount rates.

P-2 Assume a 2020 horizon for life cycle costing. Activity subsequent to 2010, if not delineated on government supplied mission models, should be assumed equal to the average of the ten years 2001-2010.

P-3 Facilities to support one space-based OMV are provided via space station program. Additional support facilities cost should be estimated if needed.

P-4 Facilities, equipment, and crew required to maintain, support, and operate a space-based OTV, including one at or near space station should be identified and their development, procurement, and operations included in costing if used in an architecture.

P-5 Reusable vehicle/element fleet size and spares complement will be determined based upon consideration of lifetime, launch rate, operational capabilities and constraints (turnaround time, mission planning/integration, facilities throughput, etc.), reliability factors, and the probability of successfully completing all of the missions in the mission model.

P-6 In addition to the contractor established vehicle design/development test programs, the standard test program set of Table 1 shall also be used to cost and schedule the vehicle development programs for reference comparison purposes.

P-7 The nominal values used for mission/vehicle reliabilities of all transportation systems should be carefully established and the basis for these values delineated and substantiated. In addition to these contractor-established values, parametric effects of launch-to-launch reliabilities from 100% down to the minima presented in Table 2 must also be presented for each competitive architecture analyzed. Highly reliable intact abort of recoverable systems is a goal, and the effect of intact abort reliabilities should also be evaluated.

P-8 The nominal values used for useful life (number of reuses) and major overhauls of recoverable systems and elements should be carefully established and the basis for these values delineated and substantiated. Life/overhaul values should be established separately for the major subsystems, i.e., vehicle, engines and aero-assist devices. In addition to these

6.9 NASP (NATIONAL AEROSPACE PLANE)

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NATIONAL SPACE TRANSPORTATION AND SUPPORT STUDY

ANNEX H

NATIONAL AERO-SPACE PLANE PROGRAM

OCTOBER 1986

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ANNEX H: NATIONAL AERO-SPACE PLANE (NASP) PROGRAM

The NASP Program is an on-going national program, and is therefore included as an integral part of the NSSD Space Transportation Architecture. The current phase of the effort is devoted largely to technology development. Many of these technologies will apply directly to future rocket-powered space transportation systems.

1. PROGRAM

The goal of the National Aero-Space Plane Program, a joint DoD/NASA program, is to develop and demonstrate hypersonic and transatmospheric technology for a new class of aerospace vehicles powered by airbreathing rather than rocket propulsion. A family of operational vehicles, built on the technology developed in the National Aero-Space Plane Program, could include a next generation space transportation system, military aircraft, and a hypersonic cruise transport. The program is structured to provide a validated technology base by the mid-1990's for single-stage-to-orbit vehicles using airbreathing propulsion as an option for the next generation manned vehicle. If the NASP technology objectives can be achieved, an order of magnitude reduction in payload cost to orbit appears attainable with flexibility of operation and basing. The technologies also have application to hypersonic aircraft for sustained hypersonic cruise in the atmosphere providing the potential for rapid point-to-point travel on the earth.

In 1984 and 1985, a Phase I Concept Definition, or feasibility study (see Figure 1), was conducted by the government to determine if the key technologies were sufficiently advanced to warrant proposing the NASP program. Based on the positive outcome of that study, the NASP program was proposed; and on February 4, 1986, President Reagan announced the program to the Congress and the Nation during the State of the Union Address and directed NASA and the DoD to proceed. Since future aerospace vehicles based on the technology developed in the program will be of benefit as both civil and military systems for aircraft and space transportation applications, the DoD and NASA have therefore combined their resources and expertise in this joint program.

The current Phase II activity focuses on developing the NASP technologies and consists of three parts: (1) development of the key enabling technologies in propulsion, materials, structures, and aerodynamics, this development to take place in government laboratories and in industry; (2) development of propulsion system components and, subsequently, a large-scale propulsion system module, as close to flight weight and size as ground facilities will accept, which will be designed, built, and tested by industry; and (3) conceptual design of vehicle configurations and development of large-scale airframe components that will be designed, built, and tested by industry. In the second area, Phase II propulsion contracts were awarded two engine companies in April, 1986, with a third engine company added subsequently. In the third area, Phase II contracts were awarded in April 1986 to five airframe companies. At the end of the first part of Phase II, two engine contractors and two or three airframe contractors will be selected to continue through completion of 199 Phase II. This phase should be completed in [redacted] and will be followed by a technology readiness assessment and decision point on proceeding with the Phase III flight research program. [redacted]

With approval to proceed with Phase III, one engine contract and one airframe contract will be awarded to design and build the experimental vehicles for the flight research program. The plan is to build two experimental vehicles for flight testing and another vehicle for ground tests and spares. Funding for the NASP program includes about [redacted] for Phase II, [redacted]

$1 Billion

The experimental vehicle, officially designated the X-30, will be used to extend the development of the technologies to higher Mach number and altitude conditions than can be fully simulated in ground facilities. It will also validate the integration of the technologies and demonstrate their performance throughout the flight envelope. The performance goals for the X-30 vehicle include demonstrating the technologies for horizontal take-off and landing from conventional runways, sustained hypersonic cruise in the atmosphere, acceleration to orbit and return, long-life reusable systems, and more conventional airliner-like operation.

2. AERO-SPACE PLANE CHARACTERISTICS

Although the aero-space plane is characterized as an airplane that will fly to orbit, there are major differences between prior aircraft and this vehicle. The unique feature that distinguishes the aero-space plane design and capabilities from current aircraft (and rockets) is the advanced airbreathing propulsion system that must provide required thrust from takeoff to close to orbital speed and operate in the demanding environment across the speed range. Another major difference is the degree of integration required between the airframe and the airbreathing propulsion system, resulting from the strong interdependence of the vehicle and engine flowfields. The aero-space plane design takes advantage of the flow compression developed through the vehicle forebody flowfield ahead of the inlet to produce the elevated pressures required for the combustion process, and further uses the aft undersurface of the vehicle as a portion of the engine exhaust nozzle. As a result, the performance of the airframe and the engine is strongly coupled, and they must be carefully integrated to produce the desired overall vehicle performance.

3. TECHNOLOGY DEVELOPMENT

Significant progress has been made in key aero-space plane technologies, particularly during the last decade, in air-breathing propulsion, aerothermal structures, and computational fluid mechanics. Phase II of the NASP program focuses and accelerates the further development of these key technologies specifically for the aero-space plane through efforts in both government and industry laboratories. These efforts include a program to mature the fundamental technologies and a program to provide ground demonstration of key systems or subsystem elements. This focused technology development will lead to the possibility of operational aero-space plane systems by the turn of the century.

TECHNOLOGY MATURITY

Both experimental and computational tools are being used to identify and develop the technologies, with computational capability playing a more significant role than has been possible in the past. In fact, computers will be the primary tool for aero-space plane analyses and design for very high Mach number and altitude conditions where wind tunnel simulation capability is limited. Extensive analyses and testing are already underway, addressing configuration concepts, impacts of different trajectories, various propulsion systems, materials and thermostructural concepts for the engine, hydrogen tank, and airframe, active cooling systems, cryogenic systems, etc. Extensive tests and analyses will be conducted for various propulsion concepts over a broad parametric range of conditions to develop the required technology level and ensure a thorough understanding of the low-speed, supersonic, and hypersonic engine cycles including combustion processes, internal and external flow phenomena and effects, inlet and nozzle performance levels, transition between engine cycles, etc.

The primary enabling technology for the aero-space plane is the scramjet which is needed for operation at speeds beyond about Mach 6. As a result of an extensive experimental and computational effort over the last decade, sufficient net thrust has been measured to demonstrate that a scramjet system can accelerate a large aircraft at hypersonic speeds. The scramjet design and operation have been optimized in these sub-scale tests for internal geometric configuration, fuel injection and mixing, and ignition and combustion efficiency. The capability to test reasonably-sized scramjets is limited by wind tunnel size, and achievable flow velocity, flow rate, temperature and pressure; therefore, this technology will be extended to higher Mach numbers based on computational results verified by partial simulation of selected parameters in wind tunnels. Since the net thrust of the scramjet engine is projected to be strongly sensitive to vehicle forebody viscous flow effects and also to the vehicle afterbody configuration for the high Mach number and altitude regime, the X-30 flight research program is required both to further develop and to demonstrate the technology above Mach 7.

The computational power of today's supercomputers is an enabling capability for the complex analyses of the aero-space plane configurations, aerodynamics, aerothermal structures, controls, etc. Supercomputers in government laboratories and in industry will be used extensively in the modification and application of existing codes for analyses of aero-space plane configuration aerodynamics, trajectories, controls, structural concepts, and subsystems, benefits and penalties. With this computer power, the full 3-dimensional viscous flowfields are being calculated for potential aero-space plane configurations, including internal flows, boundary layers, shock interactions, etc.

The requirements for structural materials for the aero-space plane center around 1) the need for high strength-to-weight at low temperatures (low speeds) where gust loads dictate the design criteria, and 2) a high temperature capability with a substantially lower strength-to-weight requirement, since pressure loads will be considerably less at hypersonic speeds where heating is highest. For acceleration to orbit and reentry, the structure will be designed and the technology developed to accommodate the significant total heat load and high peak heating loads. For sustained hypersonic cruise in the atmosphere, the dominant factor is flight at hypersonic speeds; as a result, a more efficient hydrogen tank insulation system will also be designed and developed to minimize boiloff of the liquid hydrogen. With the recently developed capability for conducting fully integrated fluid-thermal-structural analyses, minimum weight structures will be designed using this technique for the required supersonic and hypersonic conditions precluding overly-conservative structural designs with their large weight penalties.

There are a number of candidate structural materials for the aero-space plane including titanium, superalloys, advanced carbon-carbon, and high temperature composites. High temperature metals and advanced carbon-carbon, the latter having improved properties over the carbon-carbon on the Space Shuttle, are well characterized. These materials will be evaluated for the fuselage, tank, engine structure, etc., in order to identify and develop the materials and structural design combinations, and the associated joint, fastener, and fabrication technologies, that provide the needed performance at the lowest structural mass fraction.

For those areas of the vehicle where the temperatures are projected to reach levels beyond the capability of available materials, such as the leading edges of the engine splitter plates, the inlet cowl, the fuselage nose, etc., the structure will require cooling. Various techniques will be evaluated and the technologies extended to the required levels through experiments and analyses specifically for application to and demonstration on the X-30 vehicle. Candidate cooling techniques include hydrogen regenerative cooling and film cooling for large areas such as the combustion chamber walls, and heat pipes and liquid metal heat exchangers for very localized hot spots on the vehicle.

TECHNOLOGY DEMONSTRATION

In addition to the laboratory technology development and small scale demonstrations described above, Phase II of the NASP Program includes major large scale demonstrations of critical system and subsystem elements. These demonstrations, performed primarily by the industry, focus on major airframe components and propulsion systems which can be ground tested prior to experimental vehicle application and will include:

- Full scale propulsion modules and components
- Cryogenic tankage/TPS
- Integrated wing-body thermal structures
- Actively cooled nose cap - proof of concept
- Wing/tail leading edge cooling
- High temperature seals

The NASP program emphasizes these enabling technologies as well as avionics and controls, cryogenic systems, environmental control, instrumentation, flight simulation, and pilot/vehicle interface. With the specific exception of the airbreathing propulsion technology, these technologies will be of significant benefit and directly transferrable to future rocket-powered space transportation systems.

4. APPLICATION STUDIES

The full spectrum of potential NASP roles will be addressed in applications studies, ranging from single-stage-to-orbit space launch to sustained hypersonic cruise within the atmosphere. The space transportation application, as a follow-on to the Space Shuttle, represents both the highest technical challenge and potentially the greatest operational payoff of the NASP technologies. An operational aero-space plane could offer the potential for an order of magnitude reduction in payload cost to orbit with the flexibility of a variety of launch and recovery sites (runways). The program will assess the range of vehicle payload capabilities by focusing on aerodynamics, structural, propulsion, and subsystems scaling.

Approximately $8M of the Phase II program is directed toward operational vehicle system application studies and technology for associated life cycle cost reduction approaches. The latter area includes manpower reduction, reliability and maintainability, logistics, autonomy, supportability and other aspects which may be incorporated into Phase III as part of the flight research program. For example, the major cost drivers of reusability and rapid turn-around will be demonstration objectives.

5. SUMMARY

[redacted] The NASP Phase II Program [redacted] (Technology Development) is well underway and includes a "core" program leading to the maturity of key subsystem technologies and a demonstration program when the critical components are sufficiently tested to permit initiation of a experimental flight vehicle phase (Phase III). Phase II also addresses preliminary vehicle designs and potential system applications.

With the successful demonstration of the very advanced and innovative technology of the NASP program, the Nation will have broader options available for a next generation of launch vehicles and aircraft with capabilities that will clearly maintain world leadership for decades to come in both space and air transportation.

NASPprosc
VAL2

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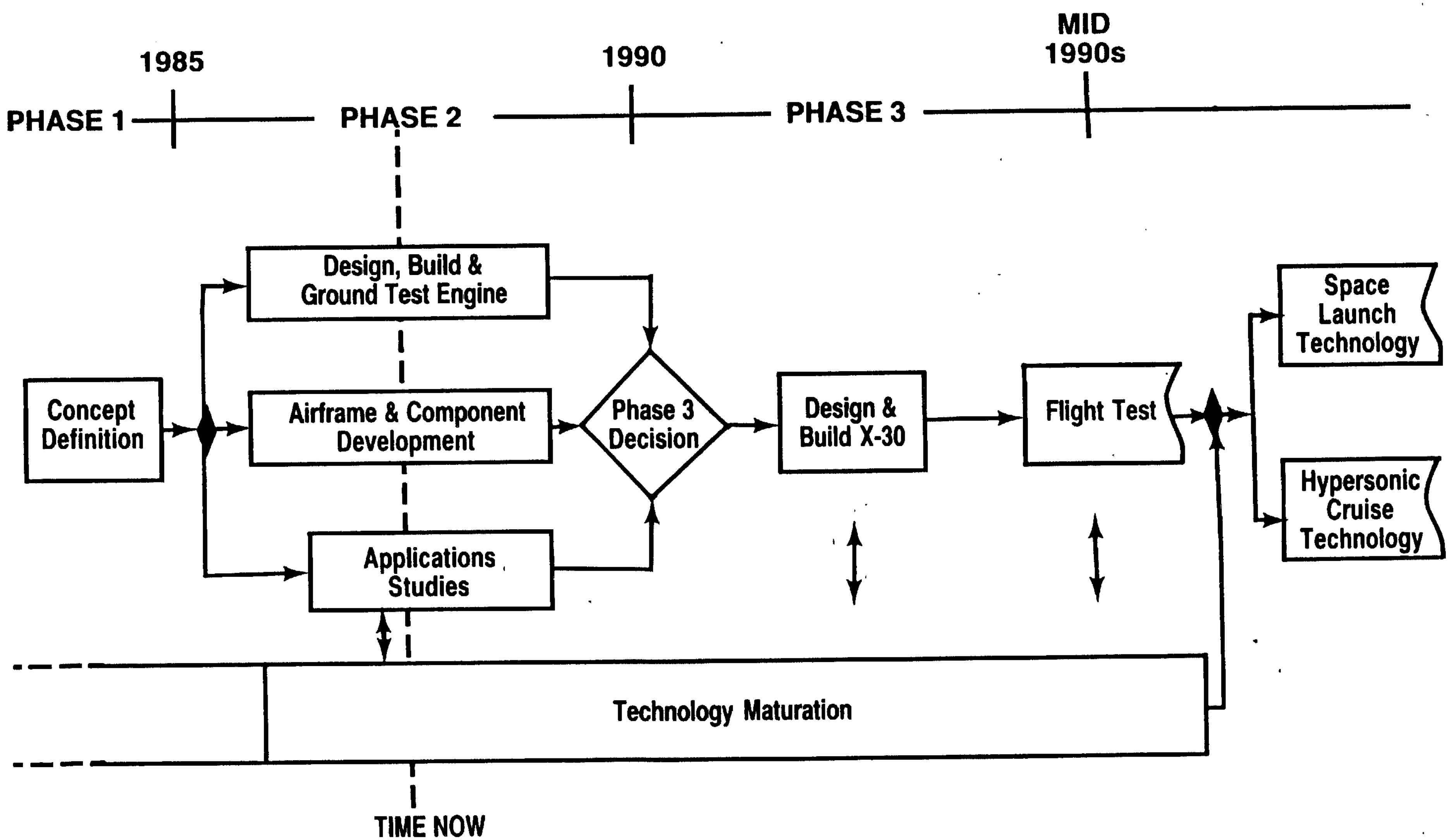
Fig 1 **NASP PROGRAM SCHEDULE** (Updated as of 30 Mar88)



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X-30 PROGRAM GOALS

- MANNED SINGLE STAGE TO ORBIT AIRBREATHING VEHICLE
- HYPERSONIC CRUISE/SUBSONIC FERRY
- HORIZONTAL TAKE-OFF AND LANDING ON CONVENTIONAL RUNWAYS
- FULLY REUSABLE
- POWERED GO AROUND CAPABILITY

$\underbrace{\hspace{10em}}_{\text{KEY NDV OBJECTIVE}}$

REDUCE PAYLOAD COSTS TO ORBIT

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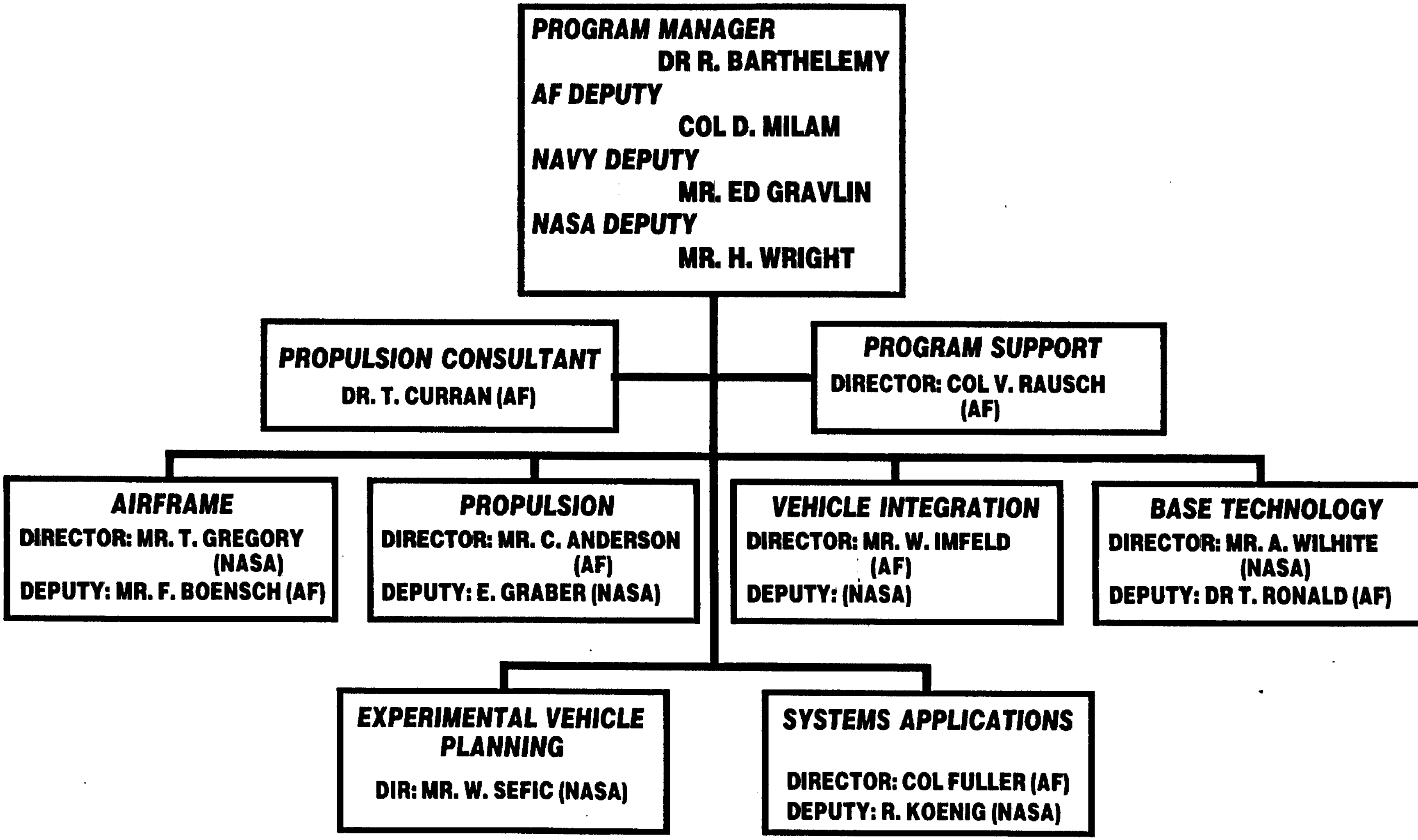
NASP JPO ORGANIZATION



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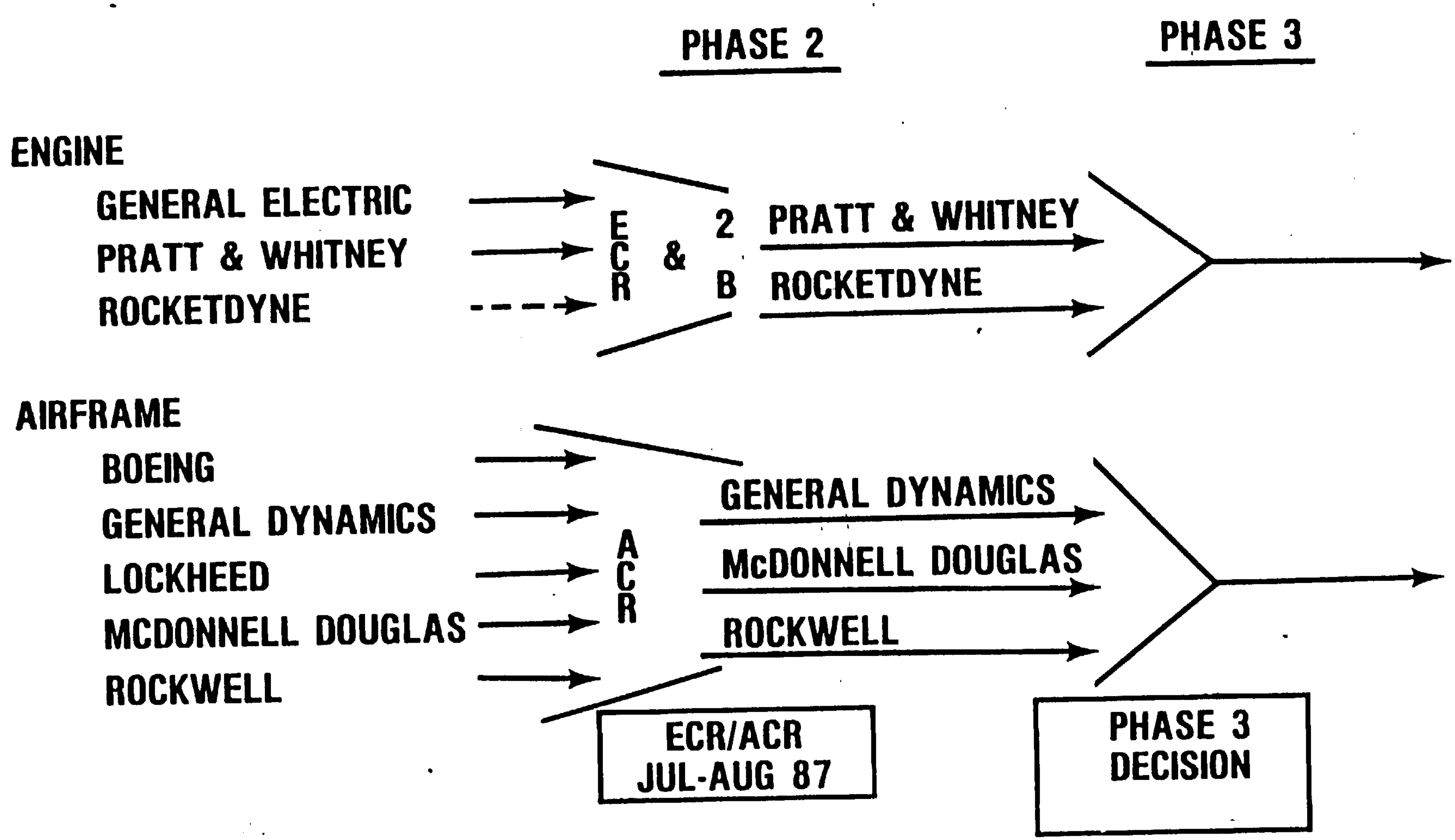
COMPETITIVE STRATEGY



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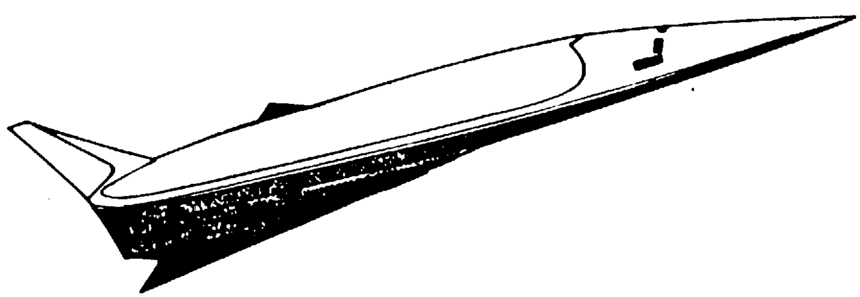
NASP

SPACE LAUNCH & ORBITAL SUPPORT

ELV	STS	A/C
~96% RELIABILITY	HIGH COST	LIMITED RANGE
LONG-LEAD LAUNCH PREP	COMPLEX PAYLOAD I/F	HIGH RELIABILITY
BENIGN ENVIRONMENT	HARSH ENVIRONMENT	RAPID RESPONSE
MINIMAL PAYLOAD I/F	COMPLEX TURNAROUND	FLEXIBLE FLT/ABORT
FAST DEDICATED FLIGHTS	ON-ORBIT REPAIR/SERVICE	LOW COST
COMMITTED AT LAUNCH	GLOBAL RANGE	FLY ON ANY AZIMUTH
LIMITED ALUNCH AZIMUTH	CREW PRESENCE	VULNERABLE TO SAMS
		LIMITED CARGO SUPPORT

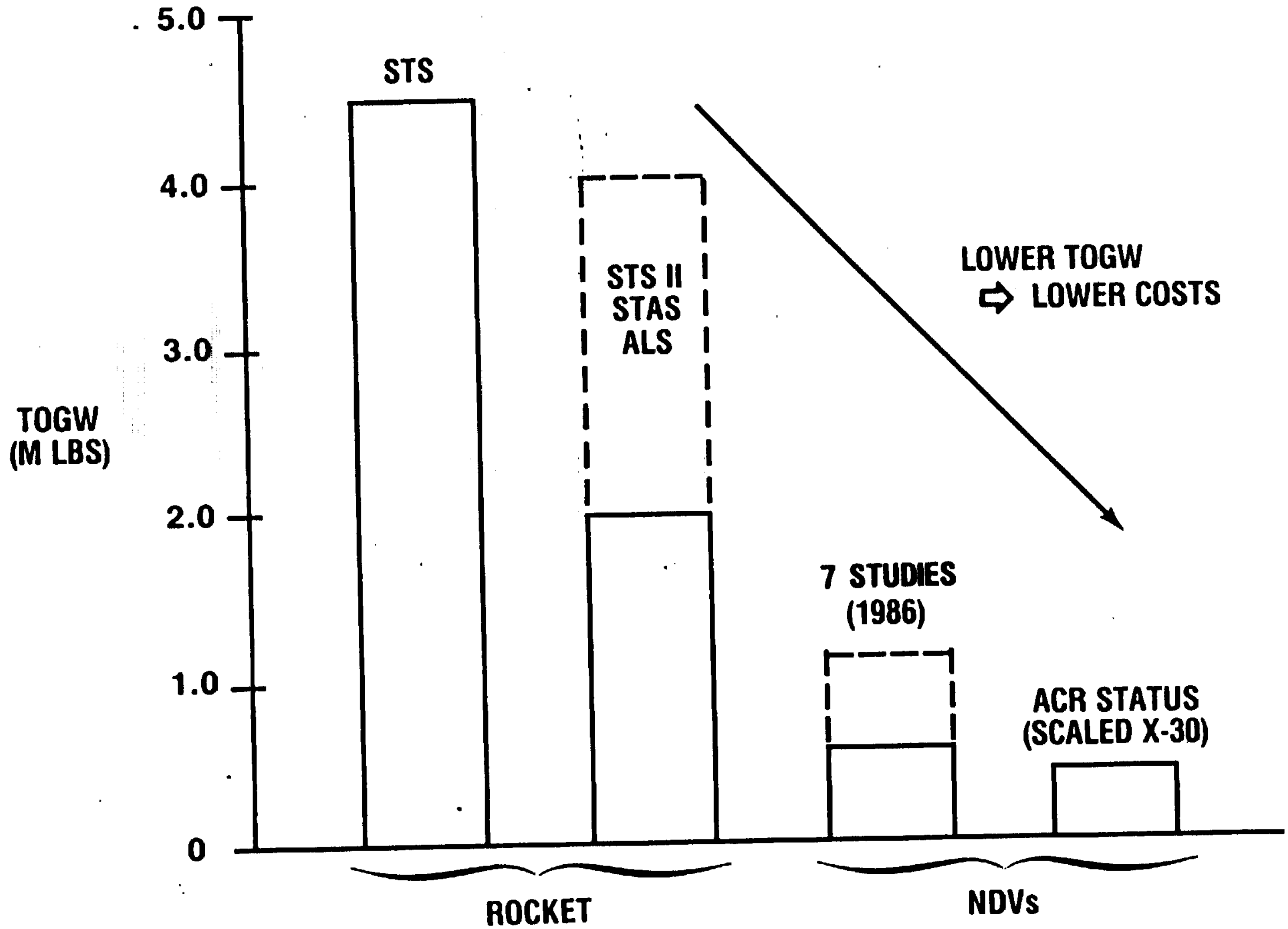


LOW COST
A/C RELIABILITY
ACCESS ALL ORBITS
PAYLOAD DEDICATED

UNCLASSIFIED

TAKE OFF GROSS WEIGHT COMPARISON

SHUTTLE PAYLOADS (65K - LBS)



UNCLASSIFIED

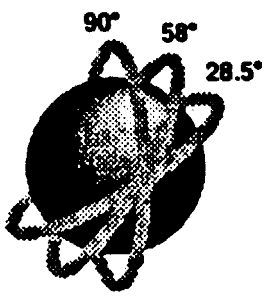
UNCLASSIFIED

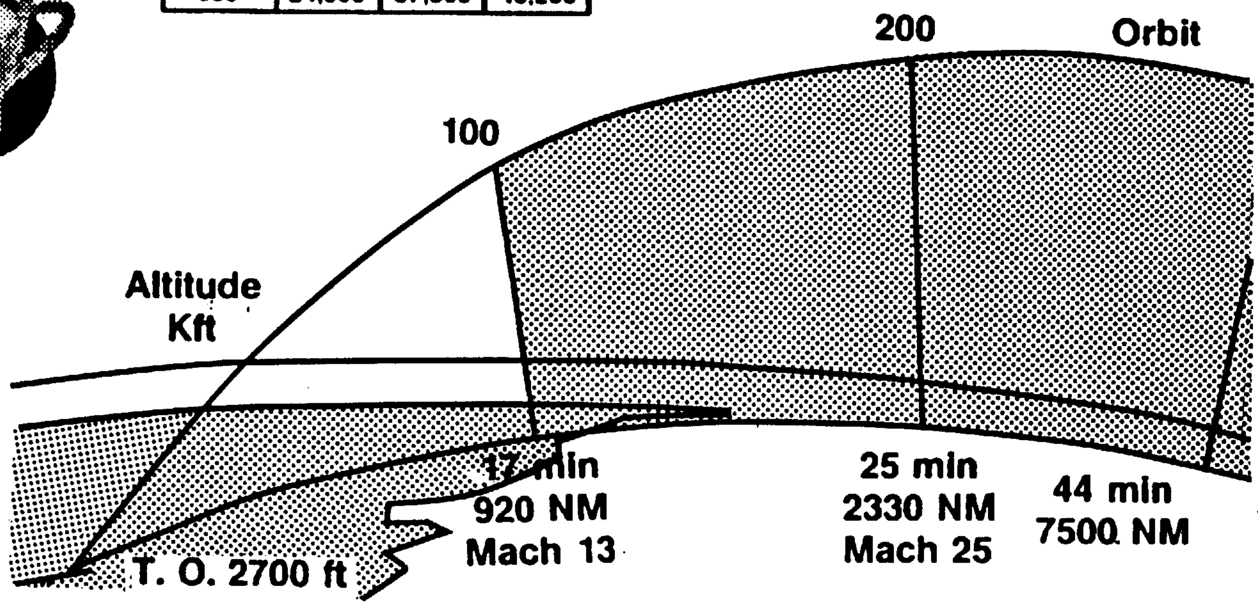
NDV SPACE SHUTTLE CLASS PERFORMANCE SCALED X-30

TOGW = 514K LBS +

FUEL FRACTION = 74%

	Payload ~ Pounds		
Alt(NM)	90°	58°	28.5°
60	57,750	89,250	108,500
150	35,000	54,250	65,800
300	24,500	37,800	46,200



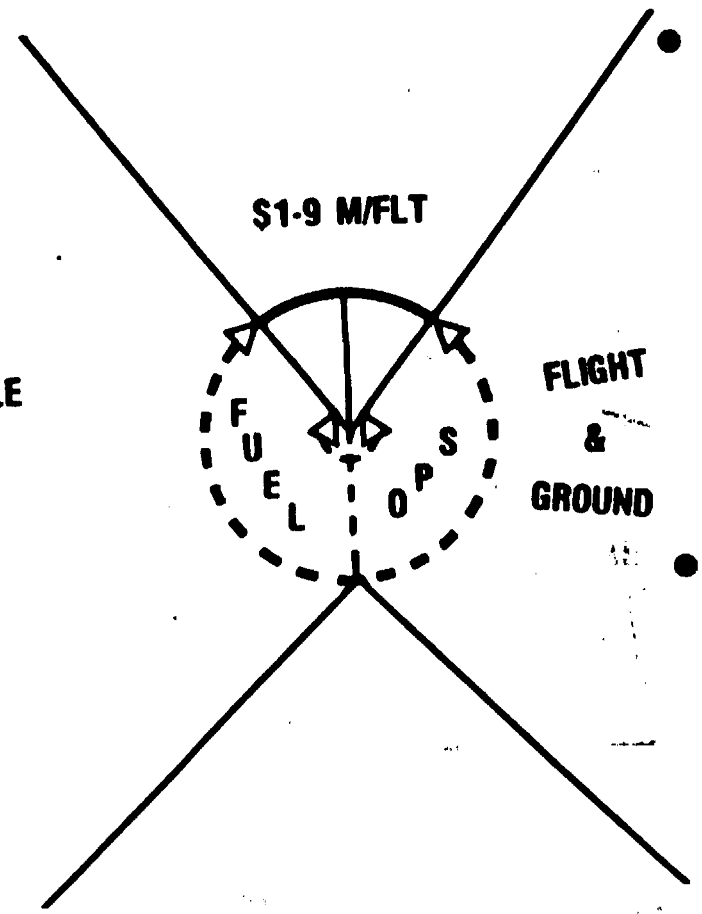


UNCLASSIFIED

NASP

UNCLASSIFIED

CONTROLLING COST DRIVERS



- INTEGRAL LOX/LH_2 SOURCE
  - 10X LESS THAN SHUTTLE
  - NO SOLIDS
  - NO HYPERGOLS

- X-30 INHERENT
  - RAPID TURNAROUND
  - BUILT IN DIAGNOSTICS
  - HOT STRUCTURE/LOW MAINTENANCE
  - MANNED A/C RELIABILITY
  - ON-BOARD AUTONOMY

- NDV BUILT IN
  - EXPERT SYSTEMS
  - MIN HAZARDOUS OPS
  - SHORT DEDICATED FLIGHTS
  - INDEPENDENT PAYLOAD PLANNING/OPS
  - CANNISTERIZED PAYLOADS

UNCLASSIFIED

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6.10 HALO (HIGH ALTITUDE LAUNCH OPTION)

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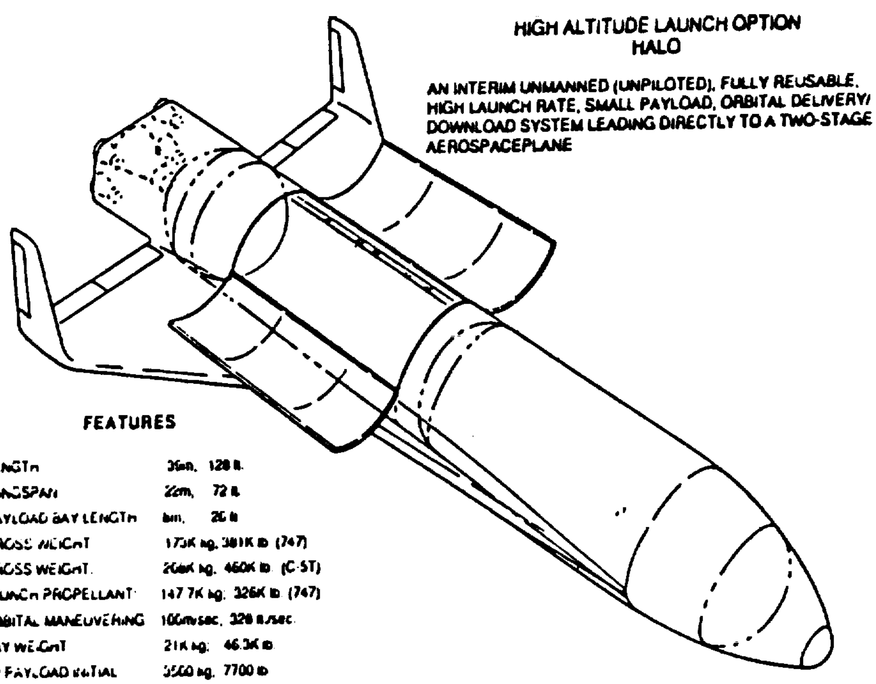
S G O E/T STUDY IPR-1 PRESENTATION by BOEING	HALO CONCEPT (HIGH ALTITUDE LAUNCH OPTION)	PRESENTED AT KSC SEPT 17, 1987

THIS CONCEPT WAS STUDIED EARLIER (1981 - 83) BY AFWAL AND AFRPL FOR APPLICATION TO THE ADVANCED MILITARY SPACEFLIGHT CAPABILITY (AMSC) MISSION. THE CONFIGURATION INCLUDED SPACEPLANE PIGGY-BACK MATING TO A BOEING 747. NUMEROUS TECHNICAL SHORTCOMINGS ARE IDENTIFIED IN THE REPORTS. THESE INCLUDED:

- MATING AT AUSTERE BASES
- DROP TANK DISPOSAL FOR ABORT
- INHERENT WEIGHT SENSITIVITY
- RUNWAY BEARING LOADS
- TAKE-OFF GEAR CONFIGURATION

A LARGE JET-POWERED AIRCRAFT CONFIGURATION THAT SOLVES / AVOIDS THESE PROBLEMS WAS STUDIED BY NASA/DRYDEN IN 1973. A COMPREHENSIVE DESIGN STUDY WAS PERFORMED WITH VERY ENCOURAGING RESULTS.

S G O E/T STUDY IPR-1 PRESENTATION by BOEING	SPACEPLANE	PRESENTED AT KSC SEPT 17, 1987



FEATURES

LENGTH	36m, 128 ft.
WINGSPAN	22m, 72 ft.
PAYLOAD BAY LENGTH	6m, 20 ft
GROSS WEIGHT	173K kg, 381K lb (747)
GROSS WEIGHT	208K kg, 460K lb (C-5T)
LAUNCH PROPELLANT	147.7K kg, 326K lb (747)
ORBITAL MANEUVERING	100m/sec, 328 ft/sec
DRY WEIGHT	21K kg, 46.3K lb
UP PAYLOAD INITIAL	3500 kg, 7700 lb
NEAR-TERM GROWTH	6000 kg, 13200 lb
FAR-TERM GROWTH	12000 kg, 26400 lb
DOWN PAYLOAD	6800 kg, 15000 lb

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TELEDYNE BROWN ENGINEERING

HALO FEATURES

- ELIMINATES NEED
  - VAB, MLP, CT, PAD, AND THE MYRIAD OF ASSOCIATED SUPPORT SYSTEMS
  - EXPENDABLE EXTERNAL TANKS
  - SRB'S & SRB RECOVERY SHIPS & FACILITIES
  - VERTICAL PAYLOAD FACILITIES
  - STANDING KSC ARMY OF 15 THOUSAND
  - SHARED CRITICAL STS FACILITIES
  - LARGE MOBILE SUPPORT TEAM AND HEAVY EQUIPMENT FOR SPACEPLANE POINT-TO-POINT TRANSFER
  - PROVIDES IMMENSELY SIMPLIFIED STS CLS EXERCISE
    - NO CRANES NEEDED FOR PIGGYBACK SCA MATE
    - C-5T CARRIES ALL SAFE AND DESERVICE GSE IN ONE TRIP TO CLS
    - POTENTIAL 24-HR CYCLE FOR STS ORBITER RTLS

- REQUIRES
  - 2 MODIFIED BOEING 747's OR 4 C5A, 2 NEW CENTER SECTIONS, NEW LOW-BYPASS, HIGH THRUST, FUEL EFFICIENT ENGINES
  - 6 NEW SIMPLIFIED DESIGN, LIGHTWEIGHT SPACEPLANES
  - SPACEPLANE HORIZONTAL PROCESSING FACILITIES
  - AIRPLANE PARKING AREAS AND SUPPORT BUILDING (NO HANGAR)
  - LOX AND LH2 STORAGE NEAR RUNWAY
    - ACCELERATED SCENARIO FILLS SPACEPLANE FROM HIGHWAY TANKERS USING QUICK/SIMPLE PROPELLANT MANIFOLD SYSTEM

HALO FEATURES (CONT'D)

- PROVIDES
  - HIGH LAUNCH RATE CAPABILITY (DAILY OR ON-DEMAND)
  - OFFSET LAUNCH CAPABILITY - FLEXIBILITY
  - LAUNCH FROM ANY 200' BY 12000' RUNWAY (73 OF THESE CERTIFIED BY USAF/MAC AVAILABLE WORLDWIDE).
  - CAPABILITY FOR 37% OF MISSION 2/II PAYLOAD SIZE AND OVER 2.5 MILLION LBS PER YEAR IN LEO
  - ON-DEMAND PASSENGER DELIVERY OR RETURN (VEHICLE MANRATED)
    - SPACE STATION RESCUE VEHICLE FOR PRICE OF MANNED PAYLOAD MODULE
  - AIRPLANE AVAILABILITY IN LESS THAN 3 YEARS AND SPACEPLANE IN LESS THAN 5 YEARS FROM GO

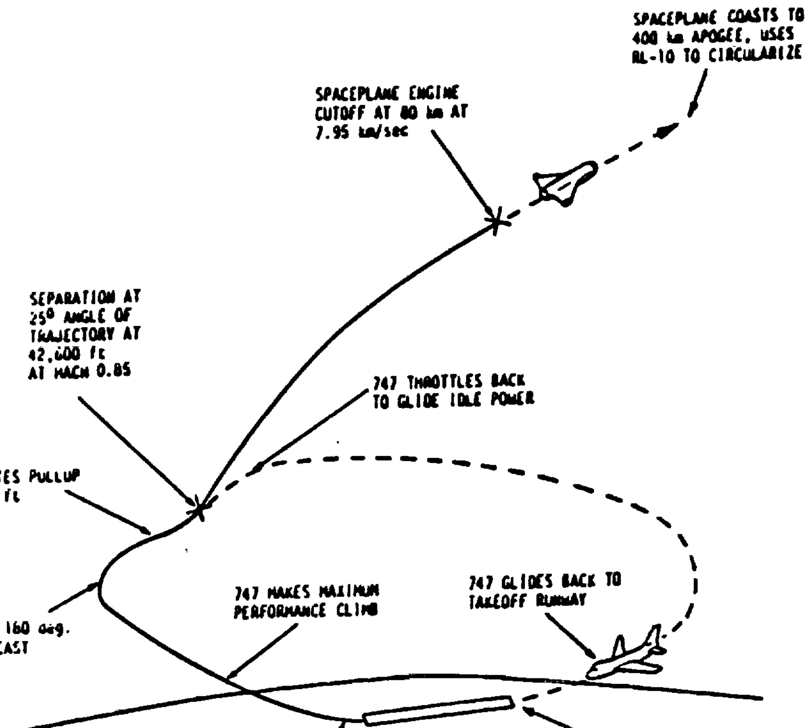
- Successful performance of the design is dependent on operational simplification relative to AMSC
  - High-G accelerated reentry unacceptable and unnecessary for small cargo/rescue vehicle
    - Skip reentry, once-around a la Sanger should be considered for structural and TPS simplicity
  - Large cross-range and resultant design impact also unnecessary for small cargo / rescue vehicle

- High launch rate dependent on spaceplane simplicity
  - AMSC spaceplane turnaround goal - 2 days
  - 5-day turnaround in a non-overtime, 5-day work week scenario requires 6 spaceplanes for daily launch schedule (sans Sunday)
  - 2.5 million lbs. per year to orbit requires 333 flights at 7500 lb P/L

- Aircraft launcher availability dependent on USAF willingness to provide 2 ea. C-5A cargo aircraft for modification

- Rapid spaceplane DDT&E/deployment dependent on existing state-of-art technology application to the very simplest possible requirements and a "skunk-works" production.

S G O E/T STUDY IPR-1 PRESENTATION by BOEING	HALO INITIAL 747 LAUNCH PROFILE	PRESENTED AT KSC SEPT 17, 1987



TELEDYNE BROWN ENGINEERING
CUMMINGS RESEARCH PARK
HUNTSVILLE, ALABAMA 35807

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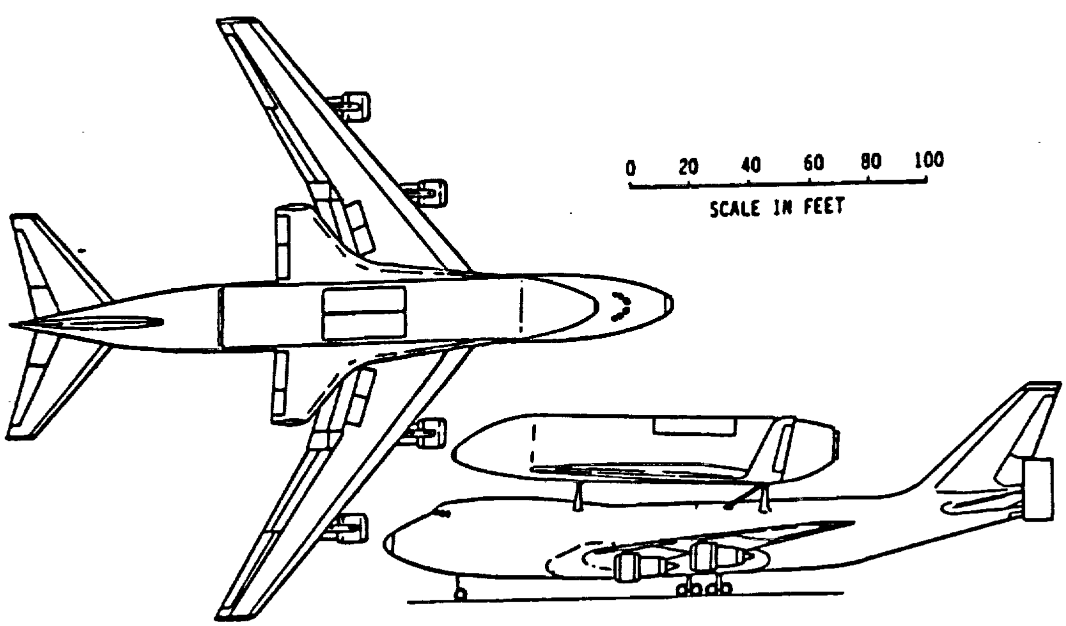
S G O E/T STUDY IPR-1 PRESENTATION by BOEING	HALO SPACEPLANE MOUNTED ON 747 CARRIER	PRESENTED AT KSC SEPT 17, 1987



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HUNTSVILLE, ALABAMA 35807

S G O E/T STUDY
IPR-1
PRESENTATION
by BOEING

SPACEPLANE VIABILITY

PRESENTED AT
KSC
SEPT 17, 1987

- REQUIRES 747 THRUST AUGMENTATION
  - 46.2K FT.; M 0.85
  - 4 EA. RL-10 PRELAUNCH FIRING
    - + 5 MINUTES
    - + LOX AND LH_2 TRANSFER FROM 747
    - + 747 AIRFRAME DEGRADATION

- LARGER, HIGH-WING AIRCRAFT SOLVES MANY PROBLEMS
  - INCREASES SPACEPLANE GROSS LAUNCH WEIGHT APPROX. 80K LB.
  - ELIMINATES AIRBORNE PROP. TRANSFER, DEWAR AND SYSTEMS
  - ELIMINATES PRELAUNCH ROCKET FIRING
  - ELIMINATES COSTLY, TIME-CONSUMING, HAZARDOUS LIFT/MATE OPERATION
  - IMMENSELY EXPEDITE/SIMPLIFY CLS ACTIVITY
  - CAN SERVE AS ALTERNATE SCA
  - CAN FERRY NEW STS EXTERNAL TANKS ON EXPEDITED SCHEDULE

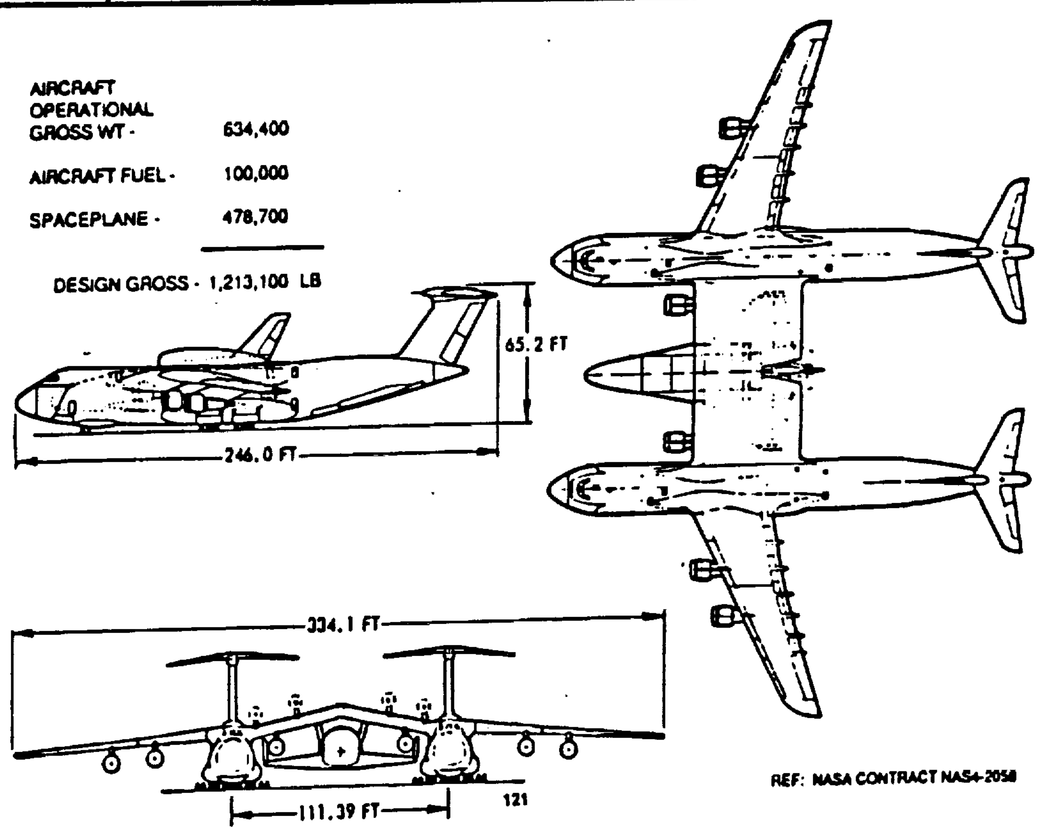
S G O E/T STUDY
IPR-1
PRESENTATION
by BOEING

TWIN FUSELAGE C-5A (C-5T)

PRESENTED AT
KSC
SEPT 17, 1987

AIRCRAFT OPERATIONAL GROSS WT -	634,400
AIRCRAFT FUEL -	100,000
SPACEPLANE -	478,700

DESIGN GROSS - 1,213,100 LB



REF: NASA CONTRACT NAS4-2058

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6.11 FOREIGN SPACE VEHICLES

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6.11.1 FOREIGN LAUNCH VEHICLE MATRIX

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International Launch Vehicles

Country/ User Agency/ Vehicle Name	Vehicle Contractor	PROPULSION: Stage No.	Engines	Stage Contractor	Stage or Motor Designation	Propellants (oxidizer/fuel)	Thrust (lb.)	DIMENSIONS & WEIGHT: Max. Dia. (ft.)*	Length (ft.)**	Launch weight (lb.)	PERFORMANCE Payload (lb.): Orbital	Escape
PEOPLE'S REPUBLIC OF CHINA												
FB-1 (CSL-2)[25]	—	1	4 x—	—	—	N_2O_4/UDMH	617,300	10.9	66.3	420,000	4,410[5]	—
		2	1 x—	—	—	N_2O_4/UDMH	154,300	10.9	39.2			
CZ-3	—	3	—	—	—	Inc. LOX/LH_2 stage(s)	—	—	—	—	—	Heavy payloads.
FRANCE												
ESA/Arianespace												
Ariane 2	CNES/Arianespace	1	4 x Viking 5 liquid	Aerospatiale/SEP	L-140	N_2O_4/UH25	601,000	12.5	59.8	490,000 (total)	4,795 (geostationary transfer)	3,200[22]
		2	1 x Viking 4 liquid	ERNO/SEP	L-33	N_2O_4/UH25	177,800	8.5	37.6			
		3	1 x HM-7B liquid	Aerospatiale/SEP	H-10	LOX/LH_2	14,000	8.5	34.2			
Ariane 3	CNES/Arianespace	1	4 x Viking 5 liquid	Aerospatiale/SEP	L-140	N_2O_4/UH25	601,000	12.5	59.8	530,000 (total)	5,690 (geostationary transfer)	3,780[22]
		1	2 x P7.3 solid	BPD	PAP	Solid	250,000	3.5	26.2			
		2	1 x Viking 4 liquid	ERNO/SEP	L-33	N_2O_4/UH25	177,800	8.5	37.8			
		3	1 x HM-7B liquid	Aerospatiale/SEP	H-10	LOX/LH_2	14,000	8.5	34.2			
Ariane 4[34]	Arianespace	1[6]	2-4 x Viking 6 liquid	ERNO/SEP	L-36	N_2O_4/UH25	152,000	7.1	62.3	To 1,033,000 (AR44L)	to 9,260 (geostationary transfer, 7° incl.)	
		1[6]	2-4 x P9.5 solid	BPD	P9.5	Solid	146,000	3.5	39.2			
		2	1 x Viking 4 liquid	ERNO/SEP	L-34	N_2O_4/UH25	177,000	8.5	37.8			
		3	1 x HM-7B liquid	Aerospatiale/SEP	H-10	LOX/LH_2	14,000	8.5	34.2			
ESA/CNES[34]												
Ariane 4[35]	CNES/Arianespace	1	4 x Viking 5 liquid	Aerospatiale/SEP	L-220	N_2O_4/UH25	601,000	12.5	82.5	523,000	4,190	—
INDIA Indian Space Research Organization (ISRO)												
SLV-3	VSSC	1	1 x solid (S-1)	VSSC	—	Solid	95,000	—	74.5	37,500	90	—
		2	1 x solid (S-2)	VSSC	—	Solid	—	—				
		3	1 x solid (S-3)	VSSC	—	Solid	—	—				
		4	1 x solid (S-4)	VSSC	—	Solid	—	—				
JAPAN												
National Space Development Agency (NASDA)												
N-2[20]	MHI	1	1 x Rocketdyne MB-3	MHI	DSV-3P-1	LOX/RP-1	172,000	8.0	74.5	297,800	4,400	770
		1	9 x Thiokol TX354-5	NM	Castor 2	Solid	52,000 ea.	2.6	23.8			
		2	1 x Aerojet AJ10-118F	MHI		N_2O_4/Aerozine 50	10,000	8.0	19.0			
			3	1 x Thiokol TE364-4	MHI		Solid	15,000	8.0	5.7		
H-1A	MHI	1	1 x Rocketdyne MB-3	MHI	DSV-3P-1	LOX/RP-1	172,000	8.0	74.5	306,460	7,100	—
		1	9 x Thiokol TX354-5	NM	Castor 2	Solid	52,000 ea.	2.6	23.8			
		2	1 x LE-5	MHI	—	LOX/LH_2	22,000	8.0	26.2			
		3	1 x UM-129A	NM	—	Solid	17,800	8.0	8.5			
H-2	MHI	1	1 x—	MHI	LE-X	LOX/LH_2	209,000	13.1	150.9	526,000	4,410	—
		1	2 x—	NM	—	Solid	23,100	5.9				
		2	1 x—	MHI	LE-5	LOX/LH_2	286,000	13.1				
ISAS												
Mu-3S-2	NM	1	1 x—	NM	M-13	Solid	283,800	4.6	47.7	136,400	1,700	304
		1	2 x—	NM	SB-735	Solid	73,700	2.4	29.9			
		2	1 x—	NM	M-23	Solid	117,500	4.6	20.9			
		3	1 x—	NM	M-3B	Solid	29,700	5.4	22.5			
USSR												
Soyuz[13] (SL-4)	—	½	16 x RD-107	—	RD-107	LOX/kerosene	900,000	33.8	62.8	720,000 (total)	16,500	—
		1	4 x RD-108	—	RD-108	LOX/kerosene	225,000	9.8	91.8			
		2	4 x RD-108	—	RD-108	LOX/kerosene	225,000	9.8	32.8			
Proton[14] (SL-8)	—	½	6 x liquid propellant	—	—	LOX/UDMH	—	—	—	—	40,000	—
		1	liquid propellant	—	—	LOX/UDMH	—	—	—			
		2	liquid propellant	—	—	LOX/UDMH	—	—	—			
SL-13[16]	—	0	6 x RD-253	—	RD-253	N_2O_4/N_2H_4-UDMH	—	—	—	—	50,000	—
		1	—	—	—	LOX/UDMH	—	—	—			
		2	—	—	—	N_2O_4/N_2H_4-UDMH	—	—	—			
Energia	—	3 stages	4 liquid strap-ons	—	—	—	—	—	12.0	400,000 5,000,000	200,000 to	—

*Excluding strap-ons. **Excluding payload.

Abbreviations:
CNES—French National Center for Space Studies
ESA—European Space Agency
GD—General Dynamics
IRFN—Inhibited red fuming nitric acid
ISAS—Inst. of Space & Aero. Sciences—U. of Tokyo
ISRO—Indian Space Research Organization
LOX—Liquid oxygen
McD/Douglas—McD/Douglas
MCI—Matsushita Communication Industries
MHI—Mitsubishi Heavy Industries
MPC—Mitsubishi Precision Co.
NEC—Nippon Electric Co.
NOF—Nippon Oil and Fat Co.
NASDA—Japanese National Space Development Agency
NM—Nissan Motors
P&W—Pratt & Whitney Aircraft
RP-1—Hydrocarbon rocket propellant
SEP—Societe Europeenne de Propulsion (France)
SLV—Standard Launch Vehicle (DOD general missions)
UDMH—Unsymmetrical dimethylhydrazine
UTC—United Technologies Corp., Chemical Systems Div.
VSSC—Vikram Sarabhai Space Center

Notes:
[1] 100-naut. mi. (115—stat.-mi.) circular orbit.
[2] Titan 34B, D/Titan 2 SLV from Western Test Range; 34D Transtage/4 from Eastern Test Range.
[3] Total thrust of strap-on rockets is shown. All Deltas ingite six at liftoff, three later.
[4] Total thrust in lb. sec. generated during solid burn.
[5] Synchronous-Equatorial orbit.
[6] Strap-on liquid or solid boosters, Ariane 4 series.
[9] Fairchild stage vehicle system with Navstar payload for placement into 100 × 10,900 naut. mi. transfer orbit.
[10] 300-naut.-mi.(345-stat-mi.) orbit from due-east launch.
[11] Multi-burn capability. Basic vehicles include Titan 3B, Atlas SLV-3A and Thor. Payloads shown are with Atlas SLV-3A booster.
[12] Centaur D-1A stages are for Atlas SLV-3D vehicles. Centaur D-1 T is a modified Centaur used in connection with Titan 3E. Both have multiburn capabilities, the D-1 T has demonstrated a zero-g coast to restart capability as well.
[13] Developed from SS-6 ICMB. "SL" is U.S. designation for Soviet spacecraft launchers.
[14] Basic civilian launch vehicle
[15] Geo-synch. transfer orbit with Atlas G. Booster.
[16] Salyut launcher.
[17] Geo. synch. transfer orbit with Titan T-34D.
[18] Length including nose fairing
[19] 450 n.mi. circular sun synch. orbit with AKM.
[20] Improved N-1 with Delta Guidance system planned for 1980-81 launch. Improved N-2 with a cryogenic stage also under study
[21] PAM-D is Payload Assist Module—Delta class, a McDonnell Douglas commercial development capable of operating either as a third stage of Delta or spin-stabilized upper stage from shuttle
[22] Two-stage escape
[23] Two-stage planetary
[24] Synch. tranfer orbit
[25] U.S. designation.
[26] 200km./69 deg.
[27] Transfer orbit for a 12-hr. final orbit period
[28] Vinf—OKM/S.
[29] Limited by 65K shuttle lift capab.
[30] Geostationary orbit.
[31] 450 n.m. circular sun sync. orbit with AKM
[32] For development launch mid-1986.
[33] For operational launches
[34] Ariane 4 is a family of launchers designated, AR40, AR42P, AR44P, AR42L, AR44LP, AR44L.
[35] Upper stage options
[36] Sea level

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6.11.2 FOREIGN SPACECRAFT MATRIX

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International Spacecraft

Nation/Organization Spacecraft Name	Contractors/ Experimenters	Weight (lb.)	Launch Vehicle	Remarks and Purpose/First Launch
ARAB LEAGUE Arab Satellite Communication Organization (ASCO)				
Arabsat	Aerospatiale/Ford Aerospace	1,492	Ariane/Space Shuttle	Two satellites C-band comm., S-band T.V. Both operational, 3-85, 6-85.
AUSTRALIA				
Aussat 1, 2, 3	Hughes	1,430	Space Shuttle/Ariane	3 domestic 14/12 GHz satellites 15 channels incl T.V. broadcasting/July 85, Oct. 85, 9-87.
BRAZIL Embratel				
SBTS	Spar(Canada)/Hughes	1,489	Ariane	2 domestic 24-transponder, C-band satellites/Feb. 1985, Sept. 1985
CANADA Telesat Canada				
Anik C1, C2, C3	Hughes, Spar	2,550	Space Shuttle	3 domestic comm. 14/12 GHz/11-11-82;6-83
Anik D1, D2	Spar (Canada)/Hughes	2,720	Shuttle/Delta	2 domestic comm. satellites, 6/4 GHz/8-26-82, 11-84.
Anik E1, E2	Spar	5,500	Ariane 4	1st quarter 1990, 3rd quarter 1990.
CHINA (Beijing)				
China 9, 10, 11	—	—	CSL-2(FB-1)	Space Physics satellites launched in single booster. 9-10-81.
China 12, 13, 14	—	—	—	Scientific sats /10-9-82,8-19-83,1-29-84.
China 15 (STW-1)	—	—	—	Experimental comsat /4-8-84
China 16	—	—	CSL-2	Earth resources sat./10-21-85
China 17	—	—	CZ-3	Second comsat 1986
China 18	—	—	CSL-2	Test sat./10-86.
China	—	—	—	2 Broadcast. Potential suppliers: RCA, MBB, Matra. 1988
Fengyun 1	—	—	CZ-3	Weather sat./1987.
EUROPEAN SPACE AGENCY (ESA)				
Meteosat-1,2	Aerospatiale led consortium	1,430	Delta 2914, Ariane	Weather data/11-22-77;6-19-81, 86-90.
Meteosat P2	Aerospatiale led consortium	1,480	Ariane 4	Weather satellite/mid 88.
Op. Meteosats MOP-1,-2,-3	Aerospatiale led consortium	1,550	Ariane 4	Geostationary weather satellite/9-88; 1-90, 1991.
ECS-1/2, 3, 4, 5	BA/Matra	1,345/1,500	Ariane 1/Ariane 3	Operational satcom/6-16-83; 8-4-84, 9/85 (launch failure), 9-87, mid-88.
OTS-2	MESH/BA/Telefunken	980	Delta 3914	Pre-operational satcom/5-11-78.
Marecs A/B2	BAe/Matra	1,350/1,375	Ariane 1	Maritime Communications/12-20-81;11-9-84.
Olympus	BAe led consortium	3,190	Ariane	Multipurpose platform 1989.
Exosat	Cosmos/MBB	1,118	Delta 3914	X-ray observatory/Re-entered 5-86.
Ulysses	STAR, Dornier led consortium	770	Shuttle/IUS-PAM D	Measure interplanetary medium out of ecliptic plane/ 10-90.
ISO	Aerospatiale led consortium	4,949	Ariane	Infrared astronomy/4-93.
Hipparcos	Matra led consortium	2,508	Ariane	Space astrometry mission/4-89.
ERS-1	Dornier led consortium	5,300	Ariane 4	Remote sensing of oceans and ice zones/4-90.
Eureca	MBB/ERNO led consortium	8,800	Space Shuttle	Retrievable carrier system/8/90, Ret. 9/91.
FRANCE National Space Research Center (CNES)				
Signe 3	Matra/CNRS	225	Soviet launcher	Gamma rays and solar UV/6-17-77
SPOT 1,2	Matra	1,540	Ariane 1/Ariane 2 or 3	Earth resources. 1986-89.
Telecom 1A,1B, 1C	Matra/Ford Aerospace	2,535	Ariane 3	Data-to-telephone satcom/1984; 1985; 1987.
TDF-1, TV-Sat1; -Sat2	Aerospatiale, MBB	2,645	Ariane2/Ariane 4	French/German broadcast sats./1987-89.
TDF-2	Aerospatiale, MBB	—	Ariane 4	Direct Broadcast./1988 or 1989.
Hermes	CNES/Aerospatiale	37,486	Ariane 5	Manned Space plane. First launch in 1995.
GREAT BRITAIN				
Skynet	BAe/Marconi	—	Ariane/Titan	UK; military communications.
INTELSAT				
Intelsat 4A	Hughes	1,745	Atlas/Centaur	6K circ.,20-transponder satellites/9-25-75.
Intelsat 5 (F1-9)	Ford Aerospace	2,281	Atlas/Centaur, Ariane	12K circ.,K-band/80-84.
Intelsat 5A (F10-15)	Ford Aerospace	4,300	Atlas/Centaur, Ariane	15,000 2-way circuits; K-band/85-86.
Intelsat 6	Hughes	4,000	Shuttle, Ariane 4	30K circ., 6/4, 14/12 GHz, 50 trans./1986/87.
INDIA Indian Space Research Organization (ISRO)				
Bhaskara-1,2	ISAC/ISRO	979-961	Soviet launch vehicle	Earth observation/6-7-77, 11-20-81.
Insat-1B, 1C, 1D	Ford Aerospace	2,534	Delta, Shuttle, Ariane 3, Delta	1 B, 8-30-83;1C, 1988, 1D, 1988.
IRS-1A	ISAC/ISRO	—	Soviet launch vehicle	Remote sensing/1988
Insat-2A, 2B	ISRO	2,000	—	Multipurpose - 1990, 1991.
INDONESIA				
Palapa 1, 2/B-1, B-2, B-2P	Hughes	660/1,388	Delta 2914/Shuttle	Domestic satcom/7-8-76; 3-10-77; recov. 10-14-84, 1-87.
JAPAN				
National Space Development Agency (NASDA)				
GMS-3, -4, -5	NEC/Hughes/—	666/—/1,100	N-2/H-1/H-1	Geostationary Metsat./8-3-84, 1989, 1993.
ETS-3 (Kiku 4)	Toshiba/GE	880	N-1	Engineering test satellite./9-4-82
MOS-1	NEC	1650	N-2	Maritime observation satellite/1987.
CS-2A, -2B (Sakura-2A, -2B)	MELCO/Ford	770	N-2	Operational, Broad-Sat/1-23-84
BS-2A, -2B (Yuri-2)	Toshiba/GE	770	N-2	Operational Broad-Sat/1-23-84, 2-86.
ERS-1	MELCO	3,090	H-1A	Earth resources sat/1991.
CS-3a, -3b	MELCO/Ford	1,210	H-1A	Operational satcom/1988.
BS 3a, -3b	NEC/GE	1,210	H-1A	Operational Broad-Sat/1990, 1991.
JAS-1	NEC	110	H-1A	Comsat for amateur radio 1986.
MOS-2	NEC	1,850	N-2	Second maritime observation. Sat 1988
ETS 5,-6	Melco	1,210/4,400	H-1/H-2	Engineering test sat 1987/1992.
EGS	Kawasaki	1,507	H-1	Geosurvey 8-86
—	—	6,600	Space Shuttle	Free flyer 1992
JCSAT 1, 2	Hughes	3,006	Ariane/Titan	Satcom 2-89.

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6.11.2 FOREIGN SPACECRAFT MATRIX

SPECIFICATIONS

International Spacecraft *continued*

Nation/Organization Spacecraft Name	Contractors/ Experimenters	Weight (lb.)	Launch Vehicle	Remarks and Purpose/First Launch
ISAS				
MS-T5 (Sakigake)	NEC	265	Mu-3S-2	Halley's comet test mission/1-8-85.
EXOS-C (Ohzora)	NEC	265	Mu-3S	Study of magnetosphere/2-14-84.
EXOS-D	—	660	Mu-3S-2	Earth plasma observation/1988.
ASTRO-½ (hinton)	NEC	265	Mu-3S	Astrophysical research/2-2-81.
ASTRO-B, -D	NEC	476, 880	Mu-3S, -3S-2, ...	Astrophysical research/2-20-83, 1990.
Planet-A (Suisei)	NEC	265	Mu-3S-2	Venus/Halley's comet mission/8-85.
Geotail	—	1,650	Space Shuttle	Geophysics. 1991.
HESP-1	—	—	—	Solar physics. 1992.
MUSES-A	—	—	MU-3S-2	Lunar survey. 1989.
LUXEMBOURG Societe Europeenne des Satellites (SES)				
Astra-1	RCA Astro-Electronics	—	Ariane 4	Communications-Ku Band. 1988 Launch.
MEXICO				
Mexico 1, 2	Hughes	1,467	Space Shuttle	Domestic comm. 6/4 & 14/12 GHz/Ap. 85; Sept. 85.
NATO				
NATO 3A, B, C	Ford Aerospace/NATO NICS	1,545	Delta 3914	Communications/4-22-76,1-27-77,11-18-78.
NATO 3D	Ford Aerospace/NATO NICS	1,675	Delta 3914	Comm., N. Hemisphere and Europe/9-84.
SWEDEN Swedish Space Corp.				
Tele-X	Aerospatiale/Eurosatellite	2,658	Ariane	Direct broadcast, video data trans./1987.
Viking	Saab Space/Boeing Aerospace	1,179	Ariane	Electrical, magnetic, auroral studies/1985.
USSR				
Cosmos Series	—	200-10,500	Various	Observation, research, scientific applications, ferret, and hunter-killer satellites launched from Tyuratam (5-26-62), Kapustin Yar (3-16-62) and Plesetsk (3-17-65). Intercosmos carrier Soviet Bloc payloads.
Cosmos 1, 374/1,517	—	2,000 lb. cl.	SL-8 (SS-5)	Sub-scale, shuttle test vehicle/6-3-82, 3-15-83, 12-83.
Shuttle	—	3.3 million total	External tank & 2 strap-on boosters	Full-scale space shuttle vehicle under development.
Synchronous Cosmos	—	—	Proton SL-12	Technology/military EW sats. Cosmos 637/3-26-74.
Meteor 2	—	—	SL-3	Temperature sounders, multispectral scanners.
Molniya 1S	—	—	Proton SL-12	First synchronous-orbiting Molniya/7-29-74.
Soyuz	—	14,500	Soyuz SL-4	Crew of 2-3 in earth orbit/4-24-67. Modified 1979.
Salyut	—	42,000	Proton SL-13	Military recon. and scientific space station; 2-4 man crew/4-19-71; 4-19-82.
Ekran/Raduga/Gorizont	—	—	Proton SL-12	Synchronous operational satcom/12-22-75
Progress	—	14,500	Soyuz SL-4	Space tanker/1/20/78
Vega 1, 2	—	—	Proton SL-12	Combined Venus lander and Halley comet flyby spacecraft/12-15-84; 12-21-84.
WEST GERMANY				
SPAS-01/01A	MBB	3,306	Space Shuttle	Reusable satellite/multipurpose free-flyer/6-18-83, 2-2-84.
ROSAT	Dornier Systems DFVLR/Goodard S.F.C.	6,000	Space Shuttle	German built, large X-Ray telescope with German, U.S. & U.K. experiments/TBD.

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6.11.3 ESA

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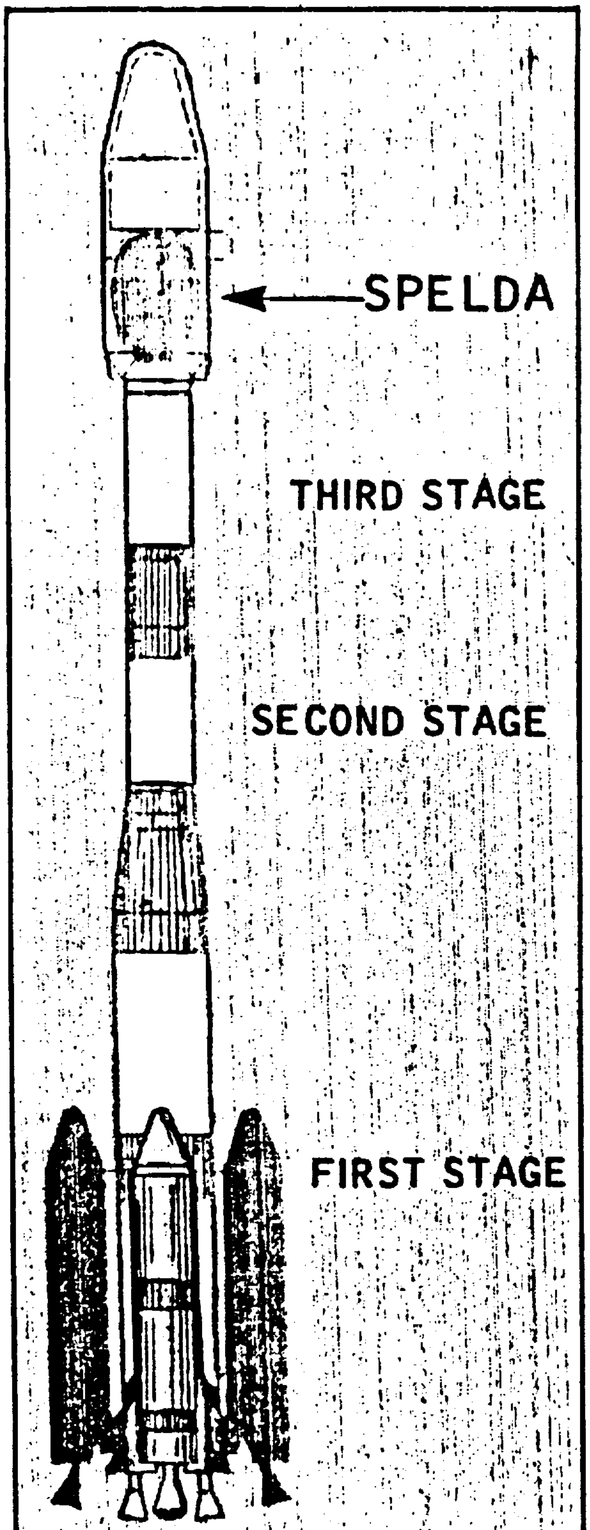
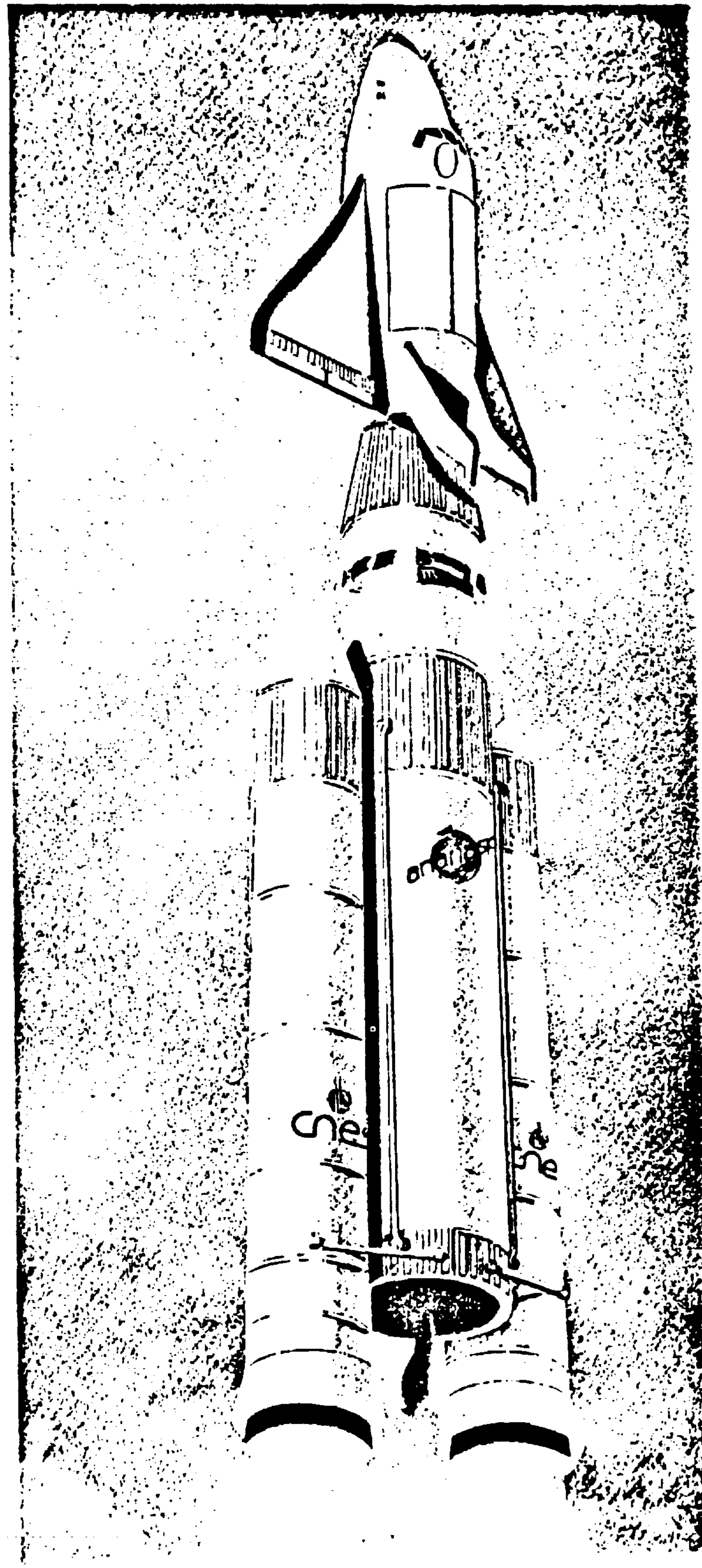


British Aerospace Spelda dual payload deployment system is shown as blue area (arrow) on this drawing of the Ariane 4 launcher.



An Ariane 5 rocket, the largest member of the European launcher family, boosts the manned Hermes mini-shuttle towards orbit. Both the shuttle and the booster are still in early stages of planning and development. *CNES*

SPACEFLIGHT, Vol. 28, Sept/Oct. 1986

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ARIANE LAUNCH MANIFEST

Flight	Month	Vehicle	Payload
		1987	
V19	Aug	Ar 3	AUSSAT K3 & ECS 4
V20	Oct	Ar 2	TVSAT 1
V21	Dec	Ar 3	G STAR III/GEOSTAR R01 & TELECOM 1C
		1988	
V22	Jan*	Ar 4	APEX 401 : METEOSAT P2, AMSAT & PANAMSAT
V23	Mar	Ar 2	INTELSAT V F13
V24	Apr	Ar 2	TDF-1
V25	May	Ar 3	SPACENET IIIR, GEOSTAR R02 & SBS 5
V26	Jun	Ar 3	EC5 & INSAT 1C
V27	Sep	Ar 4	ASTRA 1 & MOP 1
V28	Oct	Ar 2	INTELSAT V F15
V29	Nov	Ar 4	TELE-X** & SKYNET 4B

* Decision to launch ARIANE 401 between Flights 21 & 23 or between Flights 20 & 21 will be made later on.
** In the event that SSC decided to schedule TELE-X on another launch, JC-SAT will have priority on Flight 29.

Flight	Month	Vehicle	Payload
		1989	
V30	Jan	Ar 3	OLYMPUS
V31	Feb	Ar 2	JC SAT & DFS 1
V32	Mar	Ar 2	SPOT 2
V33	Apr	Ar 4	SUPERBIRD-A & HIPPARCOS
V34	May	Ar 4	INTELSAT VI F1
V35	Jun	Ar 4	SUPERBIRD-B & INMARSAT 2 F1
V36	Sep	Ar 4	TDF-2 & DFS 2 (or INMARSAT 2F2 or GSTAR IV/GEOSTAR TR1)
V37	Oct	Ar 4	SATCOM K3 & INMARSAT 2 F2 (or DFS2 or GSTAR IV/GEOSTAR TR1)
V38	Nov	Ar 4	INTELSAT V1 F2
		1990	
V39	Jan	Ar 4	EUTELSAT IIA & MOP 2
V40	Feb	Ar 4	TVSAT 2 & GSTAR IV/GEOSTAR TR1 (or DFS 2 or INMARSAT 2F2)
V41	Mar	Ar 4	EUTELSAT II B & SKYNET 4C (or ERS 1)
V42	Apr	Ar 4	INTELSAT VI F3 (or ANIK E1)
V43	May	Ar 4	ERS 1 (or EUTELSAT IIB & SKYNET 4C)
V44	Jun	Ar 4	ANIK E1 (or INTELSAT VI F3)
V45	Sep	Ar 4	EUTELSAT IIC & ITALSAT 1
V46	Oct	Ar 4	SATCOM K4 & GEOSTAR II
V47	Nov	Ar 4	ANIK E2

SPACEFLIGHT, Vol. 29, September 1987

Ariane Evolves
Arianespace, operator of the European-built Ariane rocket, has scheduled the new Ariane 4 for its maiden launch in 1988. Despite the failure of Ariane V18 in May 1986, the Ariane family has made an impressive dent in the commercial market.

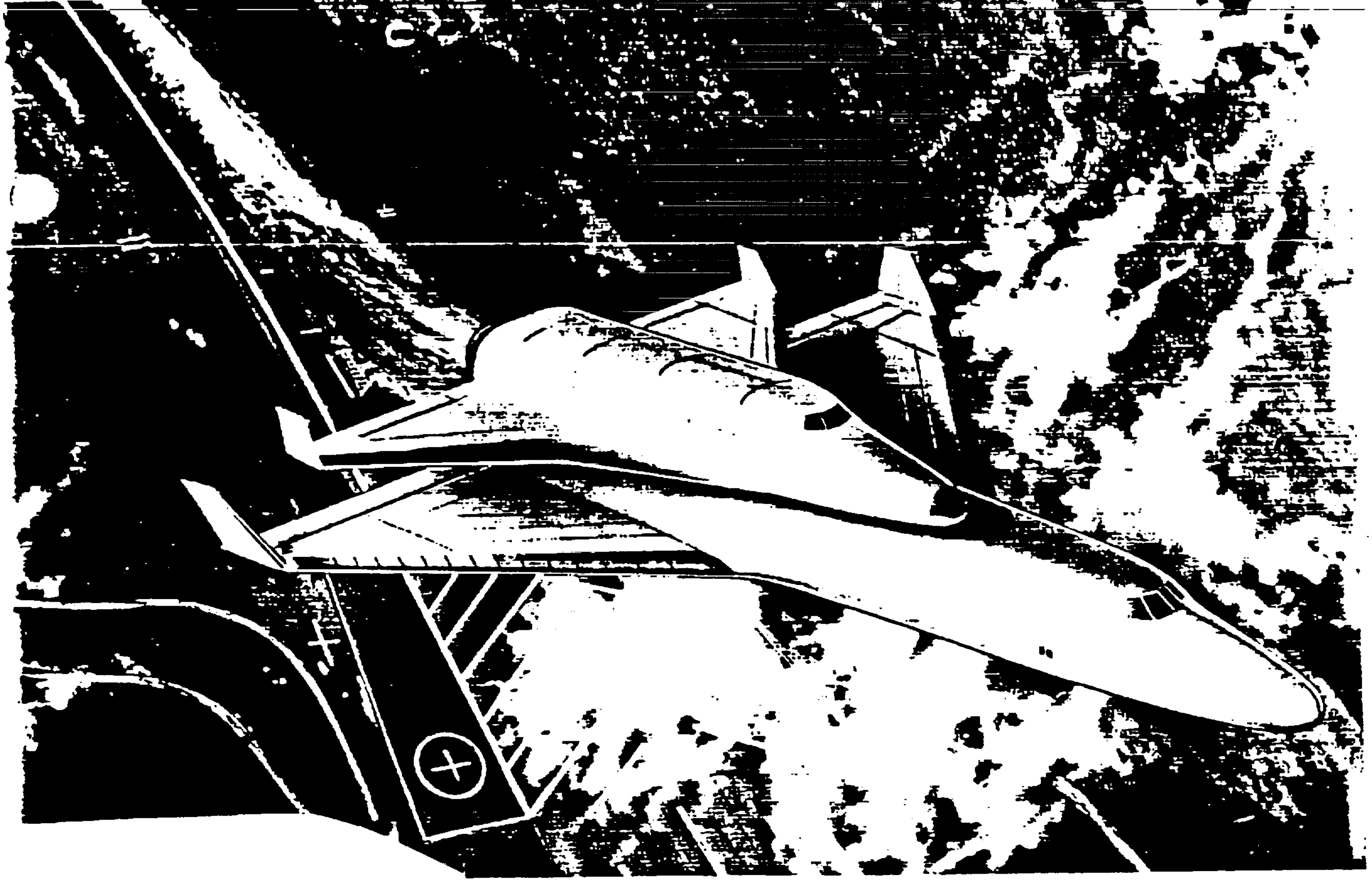
The versatility of the Ariane 4 will continue to give Europe a competitive edge through the early 1990's. The March 1986 addition of a second Ariane launch pad enables Arianespace to launch as many as 12 flights per year, although present market forecasts call for about eight annual launches in the early 1990's.

With the backlog of US launches, Arianespace has had no problem in finding customers for Ariane 4, which has a payload capability of up to 9,250 pounds. It has six configurations to meet varying launch needs and will replace the Ariane 2 and 3 launch vehicles by 1990.

France is also evaluating a Super Ariane 4 concept, able to lift 1500 pounds more, that will be used as an interim vehicle before the launch of Ariane 5. The Ariane 5 will be able to lift up to 17,600 pounds and will be launched no sooner than 1995.

At about the same time, ESA's Columbus module will be under final preparation for launch to the international space station on the space shuttle. The first module will be permanently attached to the station. Later, man-tended free-flyers will be launched by the Ariane 5.

An extended stage for the Ariane 5 in under study for the boosting of pressurised modules to the space station or to an independent European space station.



Sanger

In his paper "The Two Stage Sanger Space Transport System", Dr. H. Kuczena, of the German aerospace firm MBB, said Sanger would combine two development lines – an aircraft concept, such as Concorde, and the Shuttle concept as exemplified by the US Shuttle and Hermes.

He explained that the upper stage of the vehicle, Horus, a derivative of Hermes, would be used in conjunction with a hypersonic transport plane, Sanger. As a global transport, Sanger would be able to carry 130 passengers a distance of 13,000 km. Among propulsion systems being considered are combinations of turbo and ramjet engines for the first stage Sanger vehicle.

There are also plans for an expendable upper stage version for carrying payloads of up to 15 tons into low-Earth orbit.

Horus of 91,000 kg weight would be for manned missions only and would carry a crew of two. Uses of Horus would include servicing the space station, missions to polar orbit and reconnaissance work.

Dr. Kuczena said thinking behind the idea was to develop a system capable of being launched in Europe with the ability to cruise to an equatorial latitude for a more favourable launch location.

Horus, as a derivative of Hermes, would benefit from lessons learnt in the French-led programme. Launch costs would be 10 to 15 per cent that of Hermes with a two to four ton payload capability.

Cargus, the unmanned version, is estimated as being able to carry the same payload into orbit as an Ariane V but at approximately one third of the cost.

Development is expected to start in 1994 and operations started in 2005, after which launches should complement those of the US Vehicle.

=> 85A41527 ISSUE 19 PAGE 2763 CATEGORY 15 85/Ø6/29 2 PAGES UNCLASSIFIED DOCUMENT

UTTL: Hotol - BAe justifies its case

CIO: UNITED KINGDOM; Flight International (ISSN ØØ15-371Ø), vol. 127, June 29, 1985, p. 24, 27.

MAJS: /*COST EFFECTIVENESS/*EARTH ORBITS/*LAUNCH VEHICLES/*ORBITAL VELOCITY

MINS: / COMPOSITE MATERIALS/ LIFT DRAG RATIO/ LIQUID FUELS/ MACH NUMBER/ SPACECRAFT CONSTRUCTION MATERIALS/ THERMAL PROTECTION/ TITANIUM

ABA: O.C.

ABS: An assessment is made of the technology development and integration prospects for a horizontal takeoff and landing, or 'Hotol', launch vehicle capable of inserting 7-tonne satellites into low earth orbit at a mission frequency of 1/week in the late 199Øs. The Hotol would be of approximately the same dimensions and takeoff mass as the Concorde SST, and would employ a 'dual role' hybrid turbojet/rocket able to operate on liquid hydrogen fuel (combusted in atmospheric air at lower altitudes, and with liquid oxygen at exoatmospheric altitudes). A hypersonic L/D ratio characterized as twice greater than that of the Space Shuttle Orbiter would permit Hotol to return to a European base from an equatorial orbit, thereby saving turnaround time. Engine development is the most critical aspect of the Hotol program.

Europe Banks on Key Program Successes To Maintain Competitiveness in Space

JEFFREY M. LENOROVITZ/PARIS

Europe's competitiveness in the international launcher and satellite markets will be shaped by key program milestones this year that include the first flight of an Ariane 4 increased-lift booster and the outcome of European participation in competitions to build new communications satellites for Intelsat and Aussat.

A successful first mission for the multinational Ariane 4 booster would bolster Europe's marketing efforts for Ariane as it faces increased competition from U. S. expendables and those offered by the Soviets and Chinese. The Ariane 4 flight is planned for May/June with a three-satellite payload.

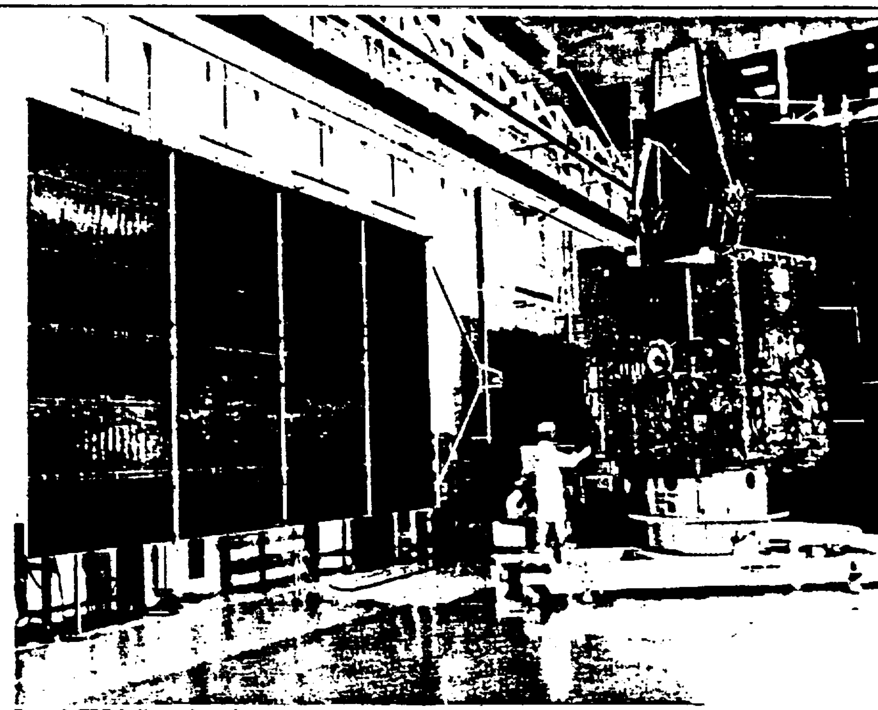
The role of European industry in building advanced communications satellites could be determined by results of the International Telecommunications Satellite Organization's Intelsat 7 and Australia's Aussat 2 competitions—in which European industry is a key participant. Bidders for the two major contracts include France's Matra, Aerospatiale, and Alcatel Espace; British Aerospace, and West Germany's Messerschmitt-Boelkow-Blohm.

"This year is a crucial one for Europe's competitive standing, and a lot is riding on what will happen in the coming months," one European aerospace executive said. "A successful launch of Ariane 4 is important for the booster's credibility, while the outcome of the Intelsat 7 and Aussat 2 satellite competitions will go a long way in determining the future of European companies in the telecommunications satellite business."

Frederic d'Allest, president of Europe's Arianespace management/marketing organization, said Ariane must demonstrate its capability this year for routine, regular launches to keep a hold on its dominant position in the commercial launch services marketplace.

"We are in an environment that is more competitive than ever, but we have established and consolidated our position as a leader in the launch services field and we plan to maintain it," d'Allest said. "We feel we have this place because we made the right choices in going to the [expendable launcher] design for Ariane well before the Challenger accident, and we have developed a range of performance improvements to create a family of vehicles as our program matured."

The first flight of the Ariane 4 increased-lift launcher currently is scheduled for the second half of May or early June, and the booster is being integrated on its mobile launch table at the Guiana Space Center's ELA-2 facility.



French TDF-1 direct broadcast satellite is similar to the West German TVsat that failed to become operational because one of its solar panels did not deploy (AW&ST Mar. 7, p. 57).

Ariane 4 is capable of launching payload masses of 4,200 kg. (9,250 lb.) into geostationary transfer orbit. The Ariane's first stage can be equipped with solid or liquid strap-on boosters or a combination of the two. The vehicle will become the primary Ariane version in operation through the 1990s, when it is scheduled to be succeeded by the heavy-lift Ariane 5 which was recently approved for development by member nations of the European Space Agency.

The three payloads to be orbited on Ariane 4's maiden flight are the European Meteosat meteorological satellite, the Panamsat telecommunications spacecraft and an Amsat amateur satellite.

Arianespace—which is responsible for Ariane marketing, management and launch—has an order backlog of 43 satellites with a booking value of $2.36 billion. Contracts for 63 satellites have been signed by Arianespace since the company was founded in March, 1981. D'Allest said Arianespace's payloads are divided nearly equally between European and non-European customers.

Program engineers expressed confidence that problems in Ariane's cryogenic third stage, which caused three of Ariane's four launch failures, have been overcome, and a regular launch pace can be resumed. The current target is to perform eight missions in 1988, followed by nine flights in 1989. Ariane's first 1988 launch is scheduled this month using an Ariane 3 version. This means seven additional firings will need to be made in the following nine months if Arianespace's 1988 schedule is to be maintained.

In addition to resolving the third-stage HM7 motor's ignition problems that were determined to be the cause of Ariane's last failure in May, 1986, program engineers also found there were temperature variations in a cooled submerged bearing in the HM7's turbopump. Much attention has been focused in the past months on the bearing's temperature variations to ensure the phenomenon is understood and to verify it does not pose a risk during flight.

"To be prudent, we want to better determine the temperature regime and the margins we have in this bearing—even though it is a bearing that never has given us a problem into flight," d'Allest said. "We have learned that you never can be prudent enough, and our policy now is to closely monitor all Ariane parameters and not let anything that seems suspicious pass without taking a careful look at it."

Ariane propulsion contractor SEP was asked to conduct testbench firings to further explore the bearing's temperature variations, and the tests are proceeding well, according to d'Allest.

A significant effort has been made to prepare the entire Ariane industrial and support network for a rapid and sustained launch rate, which is necessary to fulfill its current orderbooks and to allow Ariane to compete for new business.

The European companies involved in Ariane—SEP in particular—faced difficulties in transitioning from the development phase into a full-scale production program. A number of management and organizational changes have been made in the Ariane industrial team, including a restructuring at SEP in which the company was made an affiliate of the French government-controlled aircraft engine manufacturer Snecma.

"We're about five launchers ahead of our production plan, and we have the capability to move the third-stage motors through their checkout/acceptance procedure at the rate of about one per month," d'Allest said. "This should enable us to support a mission rate of eight launches in 1988 and nine per year beginning in 1990, even taking into account unforeseen problems that could arise."

To date, 49 launchers have been ordered in the Ariane 1, 2, 3 and 4 versions—20 of which have flown. The remaining 29 are under production or being readied for launch.

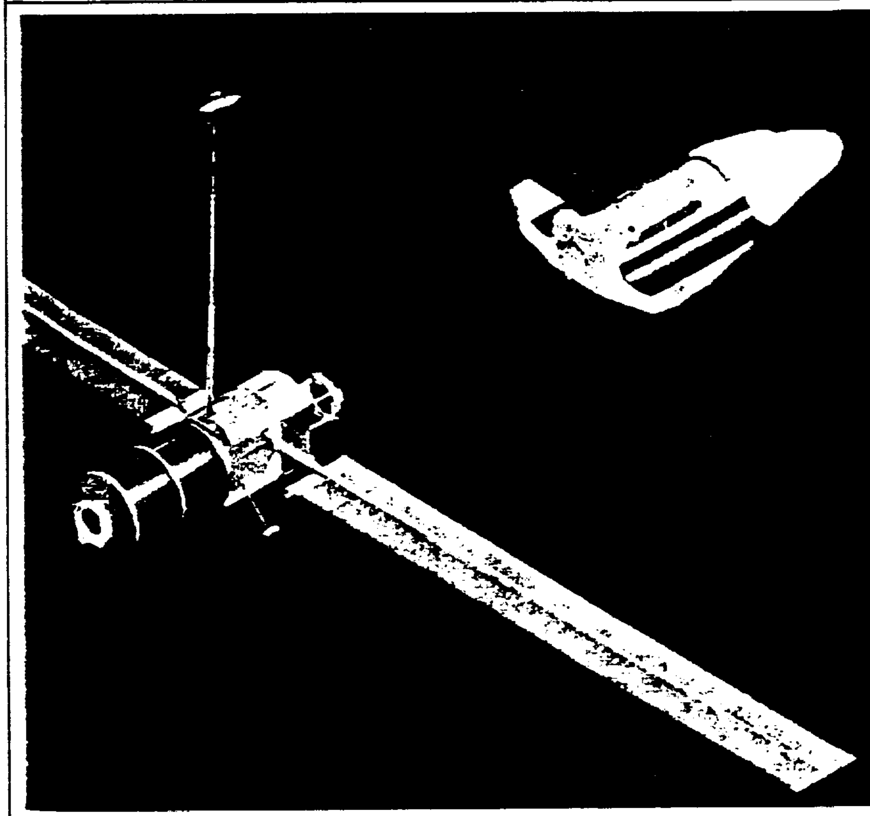
Arianespace now is negotiating with its European manufacturers to buy 50 more Ariane 4s in a move designed to cover launch vehicle requirements from 1991 through 1998, as well as to lower the industrial production and launch costs for the booster.

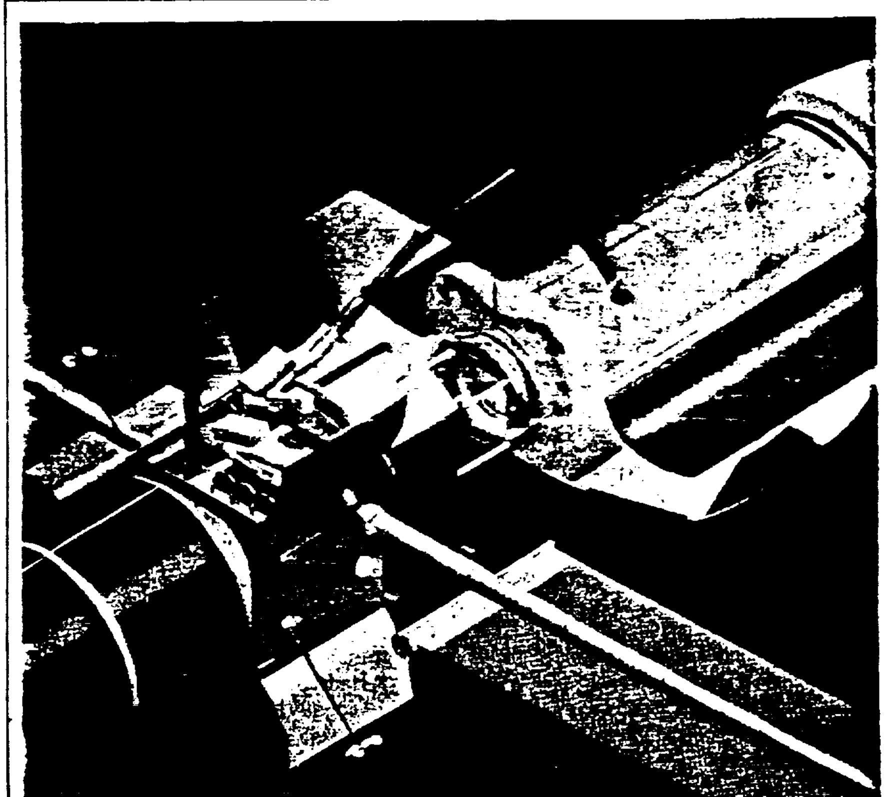
For operations at Kourou, a third complete launch team has been formed to allow a rapid mission turnaround and to provide a pool of trained personnel when replacements are necessary in the two primary teams that routinely will be working in parallel to prepare two Arianes for launch. The new ELA-2 facility at Kourou has two mobile launch tables, and a third is being built to provide additional flexibility in mission preparation.

"Overall, we are confident we have the resources to progressively build up our launch rate to the desired pace. This is a fundamental point for us and for our clients, and we are ready to meet our client requirements," d'Allest said.

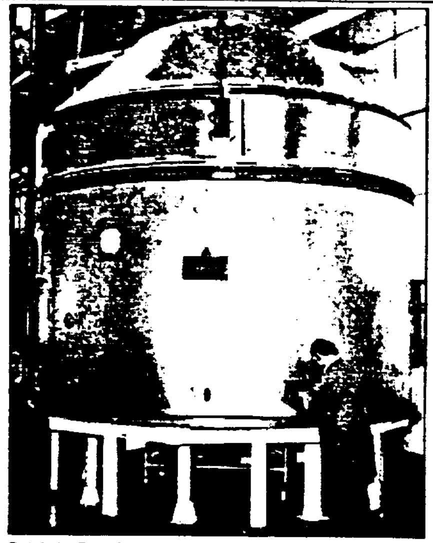
Arianespace is competing for a number of new launch contracts, including the Intelsat and Aussat telecommunications satellites, and India's Insat 2. The organization is proposing Ariane for launch of the North Atlantic Treaty Organization's NATO-4 series of military communications spacecraft. D'Allest said a number of European satellite contracts also are in preparation for expected signatures this year: with France for the Telecom 2 civil/military telecommunications platforms, with West Germany for the country's TVSat-2 direct broadcast spacecraft and with the European Space Agency for its ISO scientific satellite.

In the domain of satellite production, European manufacturers are awaiting results of both the Intelsat 7 and Aussat 2 satellite competitions in which they are participating as part of multinational teams. Industry officials said the active role being played by European companies in the two competitions represents the





Europe's Hermes manned spaceplane docks with the man-tended free-flier in orbit.



British Spelda dual-satellite payload structure for Ariane 4 carries one satellite inside its cylindrical structure. A second spacecraft is mounted atop the conical upper section.

maturing state of Europe's satellite and payload technology.

"It's clear that European companies now are taking an active part in major competitions outside Europe, so they no longer can be said to be competing in their 'captive' home marketplace," one manager at the French CNES space agency said.

Matra is leading one of the teams bidding for the Intelsat 7 production contract, which also includes British Aerospace and the California-based TRW. For the Australian Aussat 2 contract, British Aerospace has taken the lead role, with Matra acting as its partner.

"We believe Europe's aerospace industry has reached the point where a company like Matra can assume the role of prime contractor in an industrial grouping that includes a major U. S. company such as TRW," Claude Goumy, head of Matra's Space Div., said.

Other teams bidding for the Intelsat 7 and Aussat 2 contracts are GE Astro Space with Aerospatiale and Messerschmitt-Boelkow-Blohm, and a partnership between Ford Aerospace and France's Alcatel Espace.

Company executives said they hope the two recent in-orbit problems experienced by European-built spacecraft will not have a significant negative impact on the competitions for Intelsat and Aussat awards. The West German TVSat 1 direct broadcast platform built in a consortium that includes MBB and Aerospatiale failed to become operational because one solar panel did not deploy following the satellite's launch last November; while the French civil/military Telecom 1B spacecraft produced by a Matra-led consortium went out of control in January after experiencing problems with both its normal and backup attitude control systems. □

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6.11.4 JAPANESE

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HOPE

Details of Japanese efforts in the spaceplane arena were given by Mr. Toshio Akimoto, of the National Space Development Agency of Japan (NASDA), in a paper entitled "Conceptual Studies on the H-II orbiting Plane".

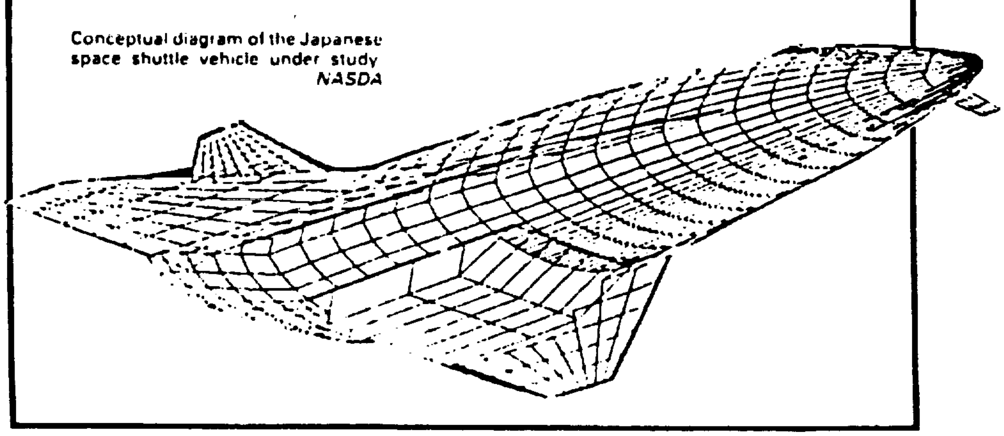
As implied in the title, the Japanese spaceplane, HOPE (for H-II Orbiting Plane), is planned for launch atop the H-II booster in a similar fashion to Europe's proposed Ariane V/Hermes configuration.

Mr. Akimoto outlined the conceptual studies being undertaken in Japan for a vehicle which would undergo its first flight test in 1995.

He said the studies had involved the consideration of five variants:

- A 10 ton unmanned spaceplane (U1) capable of lifting a three ton payload.
- A 10 ton manned spaceplane (M1) capable of orbiting a crews of two and a one ton payload.
- A 20 ton manned spaceplane (M2) capable of carrying four crew and four tons of payload.
- A 29 ton manned spaceplane (M4) with a crew of two and a one ton payload, plus internal propulsion.
- A 10 ton manned spaceplane (M1J) with a jet engine two crew members and a one ton payload.

Conceptual diagram of the Japanese space shuttle vehicle under study
NASDA



Japanese spaceplane shuttle is launched from Tanegashima Island atop an H-2 heavy booster in this artist's concept.

The first launch of the H-2 booster is set for 1992.

Hope would be 12 meters (39.4 ft.) long, with a 10-meter wingspan and two small canards. The Hope spaceplane could carry a 3,000-kg. (6,600-lb.) payload for delivery to a space station, or be used as a mini-Spacelab, even though it is not manned, according to the Japanese.

Japan Will Develop New 3-Stage Booster

Tokyo—Japan has decided to develop a new three-stage, solid-propellant booster capable of placing 4,400 lb. into low Earth orbit, a project that marks the third new high-technology expendable booster program now under way in Japan.

The new 99-ft.-long vehicle will have about 1,000 lb. more payload capability than the U. S. General Dynamics Atlas F. It will be used by the Japanese for heavy, low-orbit science spacecraft and for planetary missions to Venus and possibly other bodies.

First launch of the new vehicle is set for the early 1990s. It is expected subsequently to launch a spacecraft participating in very-long-base interferometry studies in connection with other international spacecraft and a Japanese mission to Venus in 1994 or 1996.

The new vehicle will be developed by the Institute of Space and Astronautical Sciences (ISAS), Japan's space science agency, which for more than a decade has launched about one space science satellite per year.

Japan's National Space Development Agency is preparing for the second flight test of its new H-1 booster in August and is entering advanced design of the H-2 booster, set for first launch in 1992. The H-1 can place 1,200 lb. into geosynchronous orbit, while the H-2 will launch Japan's Hope spaceplane and have the capability to place more payload in geosynchronous orbit than a U. S. Air Force Titan 34D.

The new ISAS booster has been designated as the "Next-Generation M," signifying that the vehicle will replace the current Nissan MU-3S-2, which can place 1,500-lb.-payloads in low Earth orbit. The new booster will nearly triple that payload launch capability.

The Japanese said the new booster is justified not only because of space science needs, but also as a result of growing international interest in Japanese launch of foreign science satellites now that the U. S. and European programs have been stalled by their respective launch accidents.

No contracts for the vehicle have been awarded yet, but Japanese officials expect extensive participation from Nissan, since it is the only Japanese company involved in building large solid-propellant motors.

Aviation Week & Space Technology 7-27-87

Japan Moves From US Technology

For Japan, the 1990's mean space advancement in leaps and bounds. No space programme will grow as quickly during the next decade.

Following earlier success with the N-1 and N-2 since the mid 1970's, Japan introduced the new H-1 booster in August 1986. Like the earlier boosters, the H-1 uses part US technology to lift 1200 pounds to geosynchronous orbit. However, Japan cannot use the H-1 for international services because of US trade restrictions. Japan plans seven more H-1 launches in the next five years.

A heavy-lift launcher using all-Japanese technology will be first flown in 1992. This is the H-2 which will be capable of lifting 4400 lb to geosynchronous orbit, making it more powerful than the Titan-34D.

Japan is expanding launch facilities on Tanegashima Island to launch the H-2, which will be used for re-supply missions to the International Space Station.

SPACEFLIGHT, Vol. 29, October 1987

Japan's Manned Space Goals

Japan has completed a mock-up of a space station module due to be launched by the US shuttle in 1995. An experiment platform will also be docked to the space station via shuttle or H-2. A remote arm is also being developed for the module.

Despite controversy with the US defence plans on the space station, Japan still intends to put Japanese astronauts in space through the US programme. Three astronauts have been selected for training for the Japanese Spacelab mission and one will participate on the 1991 flight.

Japan is also studying an unmanned mini-shuttle concept called Hope. Like Hermes, Hope will be launched on an expendable rocket, the H-2. First launch of the unmanned spacecraft is set for 1993 and subsequently Hope will serve as a mini-spacelab and a cargo ship capable of lifting 6,600 lb.

The second phase of the spaceplane project is the development of a hybrid air-breathing and rocket powered engine for manned use. The larger spaceplane will take off and land on a runway and development will be well advanced by 2001.

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MAJS: /*JAPANESE SPACE PROGRAM

MINS: / BUDGETS/ COMMUNICATION SATELLITES/ HALLEY'S COMET/ LAUNCH VEHICLES/ ORGANIZATIONS/ REMOTE SENSING/ SCIENTIFIC SATELLITES/ SPACE STATIONS

ABA: Author

ABS: This paper presents Japanese space activities with emphasis on aspects from the past two years. Introductory remarks outline the structure of space-related organizations and the basic principle for Japanese space activities. Among the scientific activities, the highlights in 1984-1986 are the launches of two spacecraft 'Sakigake' and 'Suisei' by M-3SII for Halley's comet exploration. In the field of practical applications, a meteorological satellite GMS-3 and a broadcasting satellite BS-2b were launched. The launch series includes the first launch of the H-I vehicle, which is characterized by the use of a cryogenic propellant for the second stage. In addition, the Space Activities Commission has approved two big projects: the development of the H-II launch vehicle and the participation to phase B activities in the U.S. Space Station program. Besides those prominent topics, major authorized programs are reviewed according to the newly revised space programs by the Space Activities Commission.

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6.11.5 USSR

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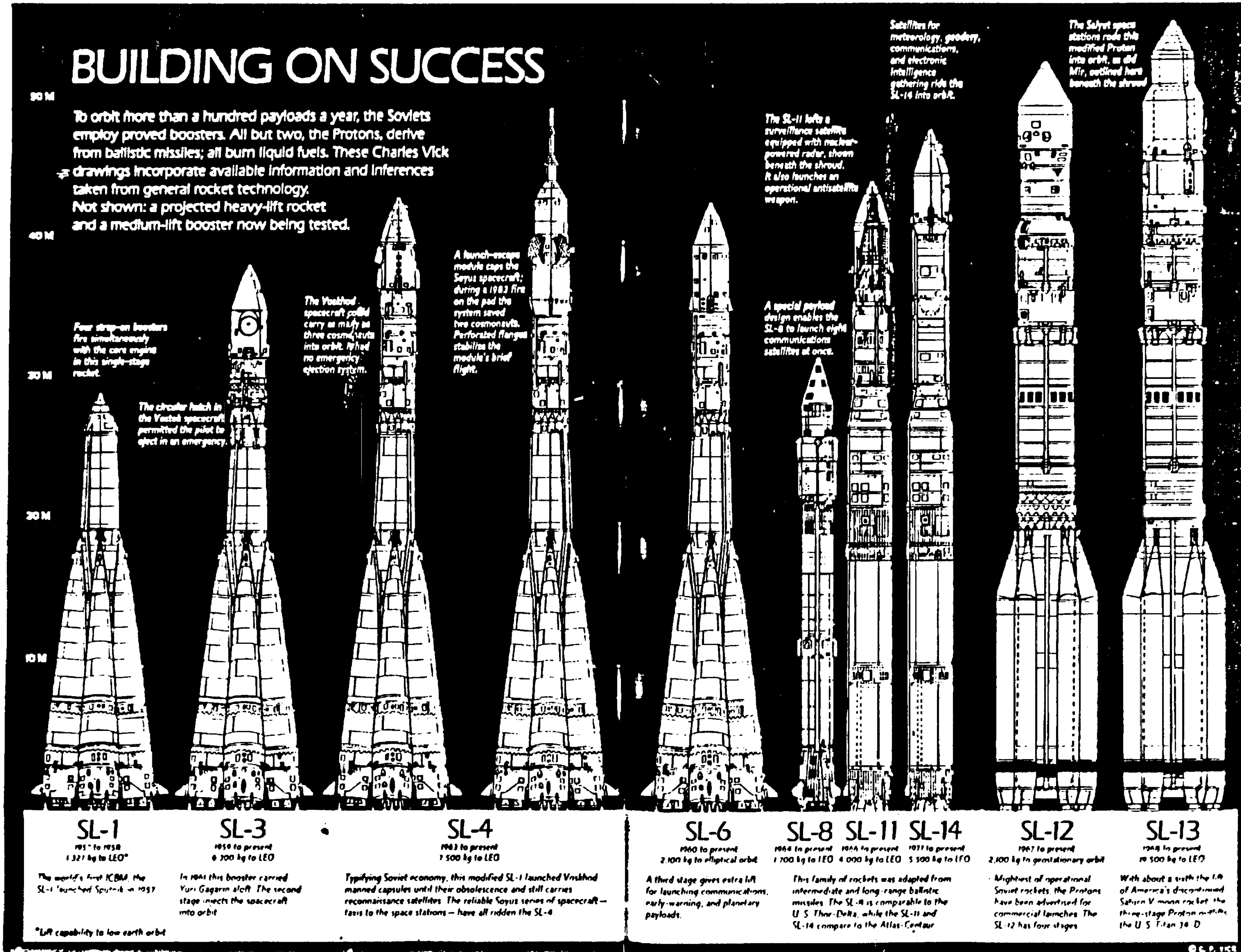


Proton is a bipropellant launcher that uses nitrogen tetroxide as oxidizer and unsymmetrical dimethylhydrazine as fuel.

The Soviets also are providing information on the prelaunch operations at the Baikonur Cosmodrome near Tyuratam. As with other large Soviet launchers, Proton is integrated horizontally, then transported by rail to the launch pad.

The major integration work on Proton's first stage starts with the installation of its central core on a large horizontal jig. The Proton core is rotated on its longitudinal axis in the jig, enabling the six strap-on boosters to be installed.

The central core of Proton contains a large tank that carries one of the two propellants. The strap-on boosters each contain one of the first stage RD-253 engines as well as a tank for the other propellant.

Ground-level thrust of the RD-253 is 1,474 kN. (331,650 lb.), while vacuum thrust is 1,635 kN. (367,875 lb.), according to Soviet data. Specific impulse at ground level is 285 sec., and specific impulse in vacuum is 316 sec.

Weight of the unfueled RD-253 is 1,280 kg. (2,820 lb.), and the weight increases to 1,460 kg. (3,220 lb.) when the engine is fueled.

After horizontal integration of the first stage is completed, it is transfered by a bridge crane to an assembly trolley for repositioning and mating with the second stage.

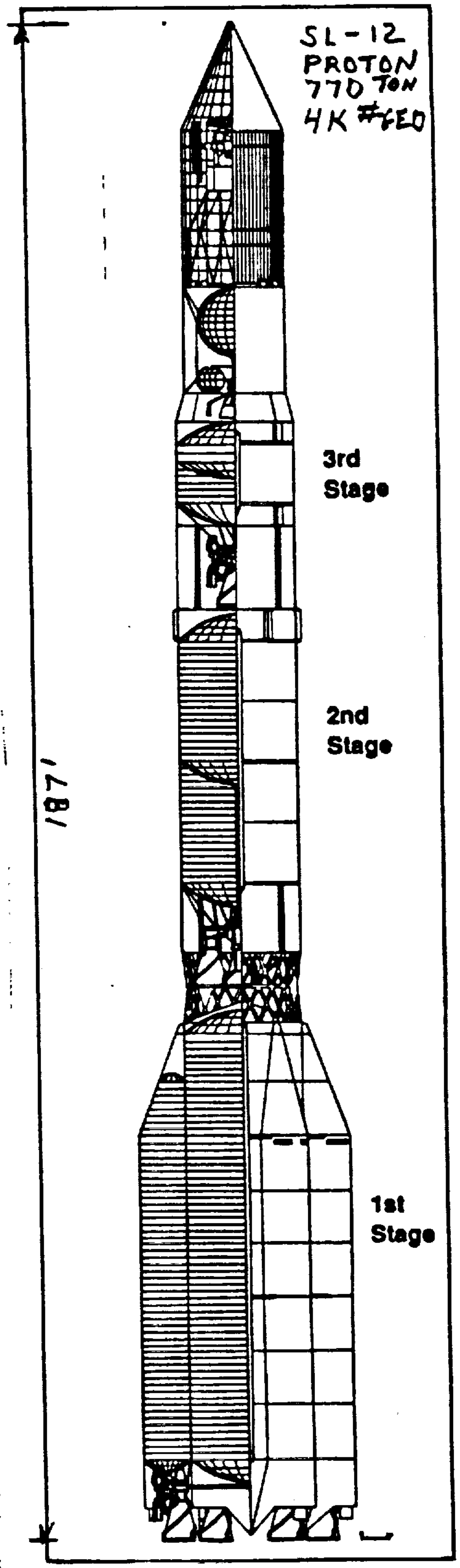
The Proton second stage is powered by four single-chamber liquid-propellent engines developing 600 kN. (135,000 lb.) of thrust each.

Soviet space program officials said Proton's third stage uses one 600-kN. engine similar in design to the second-stage engines. The third stage also has a four-chamber 30-kN.-thrust (6,750 lb.) vernier engine for flight/attitude control.

An additional stage is used on Proton when it becomes necessary to transfer payloads from low Earth orbit to geostationary orbit or place spacecraft on interplanetary trajectories. This kick stage is powered by a 85-kN.-thrust (19,125 lb.) main engine with a specific impulse of 351.8 sec. The fueled stage weighs 17.3 metric tons (38,130 lb.) and has a total operating time of 600 sec.

The Soviets also are offering the SL-4 Soyuz launcher and the Vertical sounding rocket for commercial missions. Glavcosmos officials said Vertical could fill a growing market requirement for sounding rocket launch capacity, adding that the vehicle can be fitted with a large recovery capsule.

Vertical has been used for about 15 years in a variety of scientific missions, they said. □



Aviation Week

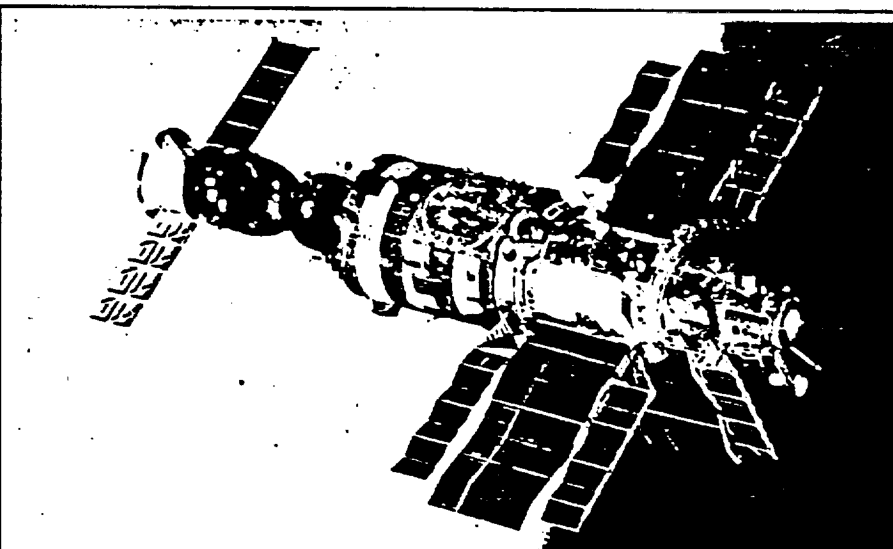
Soviets Introduce Shuttle, Energia To Bolster Space Launch Capability

WASHINGTON

The Soviets will greatly expand their space launch capability and flexibility over the next five years by introducing the Energia and manned shuttle heavy boosters and undertaking a wholesale modernization of its military satellite capability.

The Soviets will also continue conducting and increasing tests similar to those of the U. S. Strategic Defense Initiative with a variety of space systems, and this activity will increase.

Some spacecraft have released 15-20 test objects to calibrate ballistic missile radars. These military missions arebelieved to have participated in demonstrations involving development of a strategic defense system. Two such missions were launched in 1987.



Soviet Salyut 7 station, which is currently unmanned in a storage orbit, was photographed earlier with a Soyuz docked to its aft port.

UNMANNED MISSIONS

The USSR is about to mount an ambitious series of space science missions extending into the early 21st century. At least 12 unmanned Earth-orbit science missions are planned in addition to several unmanned missions to Mars and a likely return of Soviet spacecraft to the Moon by the late 1990s.

The Soviet space program has a higher priority and receives greater funding than its U. S. counterpart.

Compared with the U. S., the Soviet program demonstrates a stronger national commitment to use space operations as an inherent element of national technological and political policy. This aggressive execution of policy will be important to the U. S./Soviet technological balance for years to come.

An examination of Soviet space initiatives during the 1980s provides an indication of their intentions for the 1990s.

"Since 1980, more than 30 new space systems have been introduced by the Soviet Union, an average of four per year," according to a new report, Soviet Year in Space-1987. The report was written by Nicholas L. Johnson, advisory scientist with Teledyne Brown Engineering, Colorado Springs, Colo., who does extensive work for U. S. Air Force Space Command.

"During four of those eight years, new manned endurance records were set [by the Soviets] and two new space stations were launched. Six sophisticated Soviet probes were sent out into the solar system while the U. S. launched none," Johnson said.

Numerous major achievements took place in 1987 alone:

- Establishment of the first permanent manned presence in space with the launch of a replacement crew for the Mir station before the original crew departed. This operation will be continued indefinitely.
- Establishment of a new manned endurance record of 326 days, important for station and advanced Mars mission planning.
- Introduction of the new Energia heavy-lift booster, a launcher five times more powerful than any previous Soviet Union booster.

> *The Soviets have also been conducting tests similar to the U. S. strategic defense initiative*

- Atmospheric flight testing of the Soviet space shuttle in preparation for its first flight, expected by 1989.
- First flight of a new-generation spacecraft conducting large-radar remote sensing. The U. S. will be unable to launch a similar vehicle until the mid-1990s.
- Introduction of new military ocean surveillance spacecraft.
- Demonstration of more flexible military imaging reconnaissance satellite operations.
- Quick recovery from the failure of two heavy Proton boosters and several satellites with little disruption of the space program.

The Soviet Union is also embarking on a space commercialization effort, attempting to market its launch services and remote sensing satellite imagery. The primary benefit from these activities will be favorable public relations. The sale of these services will do little to affect the launch plans of either the USSR or other nations in international space markets.

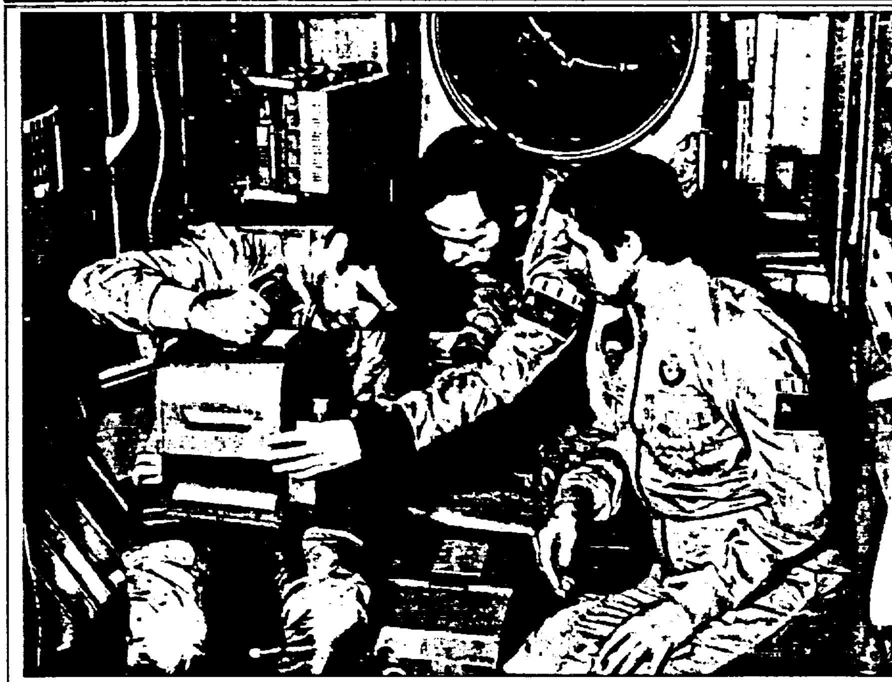
FLIGHT OPERATIONS

Flight operations with the new Energia booster, first launched last May 15, will open a new era in Soviet space operations. The Energia is capable of placing 200,000-lb. payloads into low Earth orbit. The USSR would not have designed the launcher if it were not developing a new class of heavy payloads. In comparison, the U. S. will not be able to match this capabilty for another 10 years at the earliest.

Energia will launch large space station modules in the 1990s which will solidify Soviet leadership in manned station operations. Larger station modules holding advanced equipment will open the way for new technology developments in both militiary and scientific areas.

The Energia will enable the USSR to launch the world's first battle satellites within the next five to ten years. These could be large platforms capable of attacking U. S. spacecraft or ballistic missiles, using kinetic- or directed-energy weapons.

The Soviet space shuttle, once fully operational in the early 1990s, will enable that country to engage in covert military



Soviet and Bulgarian cosmonauts are shown training in a Mir station mockup. A joint Soviet/Bulgarian mission to the Mir space station is planned for this spring.

space operations on a large scale for the first time. By using a shuttle, whose external characteristics appear the same every time, it will be much more difficult for the U. S. to analyze individual payload operations.

The shuttle will permit deployment of payloads out of range of U. S. tracking capabilities, including placement in geosynchronous orbit. This would provide an increased military capability the U. S. would be unable to counter in an emergency. The Defense Dept. is concerned that some of these geosynchronous payloads could be "space mines" with an offensive capability against vital missile-warning and communications spacecraft.

Introduction of the shuttle will permit full exploitation of space construction and satellite refurbishment, not easily done from "capsule-type" spacecraft, such as the Soyuz, used for the last 20 years.

Another new vehicle in development is the small manned spaceplane, with first manned launch on an SL-16 booster expected by 1990. The spacecraft will be the world's first space fighter, capable of quick-reaction military missions for satellite attack, inspection, ground reconnaissance and station resupply.

The introduction of these capabilities is likely to reduce the total number of Soviet launches in coming years as the program obtains more use out of individual spacecraft, according to Marcia Smith, who heads Soviet space analysis for the Congressional Research Service, Library of Congress.

Current Soviet satellites have relatively short lifetimes. An analysis conducted by Johnson showed that by the end of 1987, nearly half of all the satellites launched that year had expired. As in previous years, the number of Soviet launches outstripped those of all other nations in 1987. The USSR launched 95 missions that reached Earth orbit, carrying a total of 116 separate satellite payloads.

The United States, Europe, Japan and China combined launched a total of 15 flights during the same period.

The Soviets exhibit a strong national will to use space operations as an element of national political policy

In manned flight, the Mir space station will be the focal point of Soviet operations into the 1990s and act as a transition vehicle to the much larger station that will begin to take shape with Energia and space shuttle flights by about 1995.

"During 1987 a total of 11 [manned and unmanned] missions were flown to the Mir station, a record for annual support operations and the largest percentage (11.6%) of all Soviet space flights dedicated to manned related activities since 1978," Johnson said. This group included three manned Soyuz vehicles, seven unmanned Progress tankers and the Kvant astrophysics module.

For the first time, a manned crew was launched in the new TM version of the Soyuz, with significant computer and avionics improvements over the earlier, Soyuz T versions.

A 326-day flight on the Mir by Cosmonaut Yuri Romanenko in 1987 will likely be surpassed this year by a two-man crew, which is expected to remain on board for at least a year.

Numerous long-duration missions will be conducted to obtain physiological data for the manned Mars missions, but more routine station manning is expected to last six months.

MATERIALS PROCESSING

Over the next five years, the Mir will be equipped with several additional large modules specialized for Earth resources observations, materials processing, life sciences and other purposes.

The modernization of military satellite operations will be another primary development over the next five years.

New records were set by the Soviets with imaging reconnaissance satellites in 1987, indicating the direction of this program in the future. During 1987, the Soviets launched 28 military imaging satellites, two more than during the previous year. Overall, however, about the same number of military imaging reconnaissance satellites have been flown annually since 1980. A big difference, however, is in the number of mission days these spacecraft have operated.

"While the number of flights has remained constant, the total annual military mission days has almost tripled since 1980," Johnson said. The reason for this is the long lifetimes of more modern reconnaissance systems.

While the U. S. operates essentially only one imaging reconnaissance satellite, the USAF/Central Intelligence Agency KH-11, the Soviets operate three types in five separate orbital parameters.

During 1987, Soviet medium-duration reconnaissance spacecraft that functioned for 6 to 8 weeks were used extensively. These vehicles were often commanded to monitor specific intelligence targets. "The new fifth-generation photo recon satellites, under space testing for the past five years, demonstrated unprecedented mission profiles suggesting attainment of full operational capability in 1987," Johnson said.

One of the fifth-generation spacecraft set a new 259-day record for operations during 1987.

In another important military area, an electronic ocean surveillance satellite system "achieved a new endurance record and demonstrated more operational profiles," Johnson said. "Of perhaps even greater importance was the introduction of a much higher orbit, which might signal the first major change in the ocean surveillance program since 1974," Johnson said.

The higher altitude provides two benefits—the ability to more easily monitor polar regions and to better stay out of range of the U. S. F-15-launched antisatellite system. The latter objective may now be irrelevant, since the U. S. has canceled the F-15 Asat program to pursue ground-based directed-energy Asat systems.

The Soviets flew a total of six new ocean surveillance satellite missions in 1987, compared with five in 1986. Their ocean surveillance spacecraft constellation was higher than that however, as the newer satellites often were teamed with older satellites already in orbit.

Two of the spacecraft launched in 1987 were nuclear-reactor-powered radar ocean surveillance spacecraft. Two others were electronic spacecraft that spot ships by intercepting radio transmissions.

The two other spacecraft are classed as unknown ocean surveillance vehicles flying new mission profiles.

A review of other mission areas for 1987 illustrates trends for future operations:

■ Communications satellites—The Soviets launched 11 low-altitude communications satellites in 1987, compared with 27 the previous year. One of the missions last year carried eight satellites on one vehicle. The high number of spacecraft launched in 1986, but still operational reduced the need for more missions in 1988. Only one Molniya-3 spacecraft was launched in 1987, compared with seven in 1986. At least seven communications spacecraft attained geosynchronous orbit, one more than in 1986.

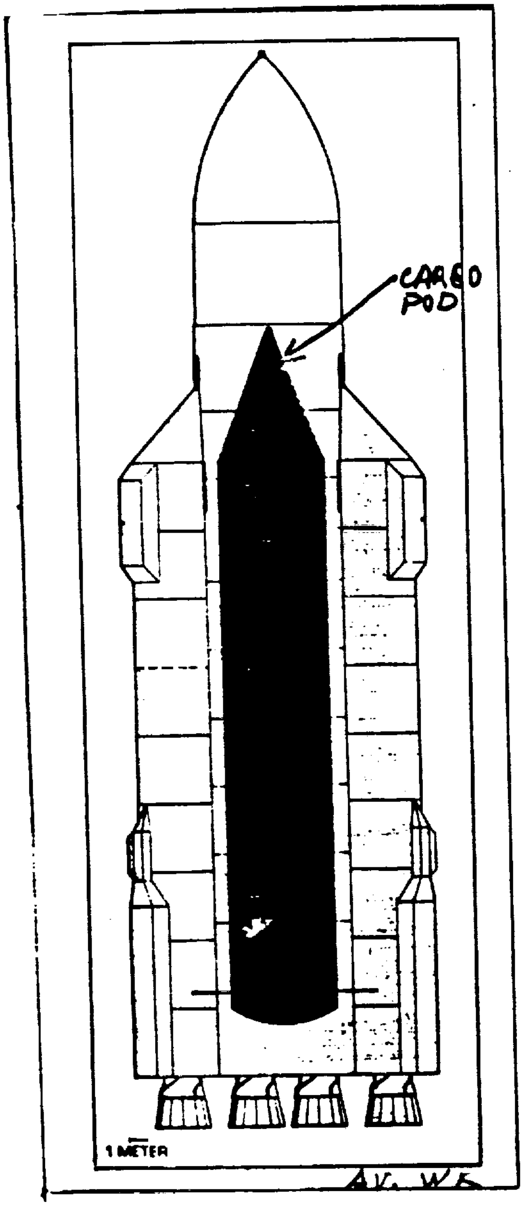
■ Navigation satellites—Six low-altitude navigation spacecraft were launched in 1987, one less than 1986. Six Glonass advanced navigation spacecraft were launched, with each mission involving three satellites on a single booster. This is three more spacecraft than were launched in 1986.

'Since 1980, more than 30 new space systems have been introduced by the Soviet Union'

■ Meteorological satellites—Two new Meteor-2 spacecraft were launched, doubling the 1986 rate. In addition, two remote sensing satellites were launched, one carrying an oceanographic radar and another Cosmos 1,870, which is a large, multidisciplinary radar platform.

■ Missile warning—The Soviets launched only three early-warning satellites in 1987, compared with seven in 1986. "The launch rate dropped dramatically in 1987 as the Soviet Union apparently reached full operational capability for the first time in the trouble-plagued 15-year-old program," Johnson said. □

AVIATION WEEK & SPACE TECHNOLOGY/March 14, 1988



"ENERGIA"
220,000# LEO
1st Launch 5/15/87
6.6M# Thrust
198' Tall
4 10X/LH_2 Engines
4.4M# Vehicle

The Promise of Energia

The maiden launch of the Energia rocket by the Soviet Union at 7.30 pm Moscow Time on May 15, 1987, marked the first time a very-heavy lift launch vehicle has been flown since the American Saturn V made flight to the Moon possible.

The 220,000 pound payload capability of Energia will be used to place large satellites and space station segments into orbit during the 1990's. A third stage for the Energia is under study which will lift 330,000 pounds into orbit. But the primary feature of the new Soviet rocket is its role as the booster for the Soviet Space Shuttle.

When used as an unmanned booster, a 120 ft strap-on payload canister runs the length of the 198 ft tall rocket. The canister will then be replaced by the shuttle during manned operations.

The Soviet shuttle relies on the engines of the Energia to reach orbit, since it carries no engines of its own. This gives the Soviet shuttle a slight payload capability advantage over the US shuttle system. The Soviet version is expected to lift up to 66,000 pounds of cargo.

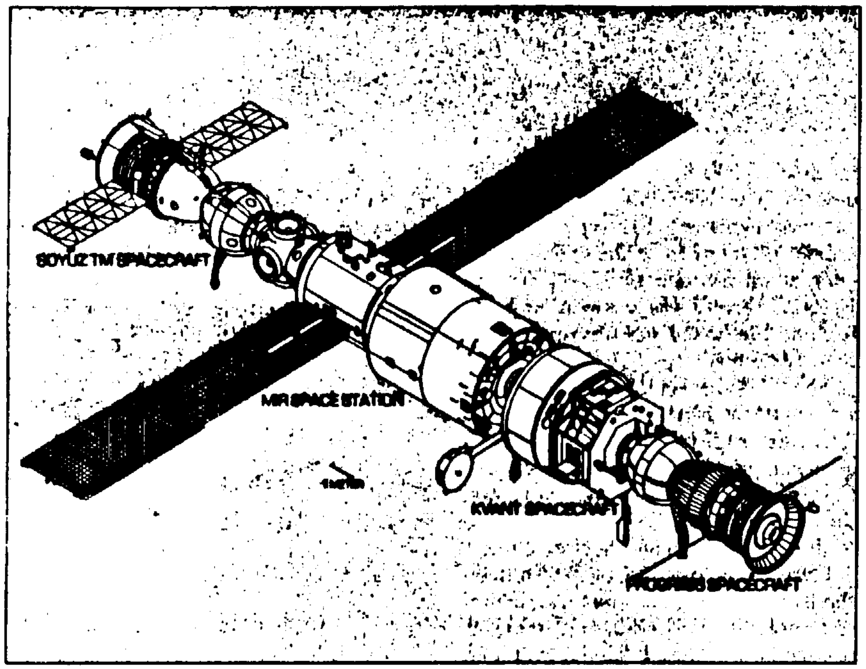
The first shuttle launch is likely in 1990, and will be unmanned. Cosmonauts will board the shuttle in 1991 or 1992 for a two-year test phase.

Fully operational by 1994, the Soviet shuttle will initially be used in conjunction with the growing Mir space station.

Unlike the US Space Transportation System, the components of the Energia system are a family of individual launchers. The Energia uses four SL-16 boosters as strap-on rockets. The SL-16 has been tested successfully following severe development problems in 1984.

Spaceflight, Oct. 1987

Soviet Union Outpaces U. S. In Station, Launch Capabilities



Daniel James Gauthier

Soviet Energia booster and the Mir space station have demonstrated capabilities in the last month that U. S. will be unable to duplicate for at least 6-8 years. Drawing at right shows the launch configuration of the Saturn 5-class Energia vehicle, which is capable of placing at least 220,000 lb. into orbit, a capability the U. S. will not regain until about 1993—20 years after the U. S. abandoned Saturn 5 operations. The Energia was launched for the first time May 15 (AW&ST May 25, p. 18). A large payload carried piggyback on the booster was colored black, distinguishing it from the light color of the rest of the vehicle. Two sets of oxygen/kerosene strap-on boosters are on either side of the oxygen/hydrogen core. Four of the vehicle's eight engines are visible in this drawing. As the Soviets assessed the Energia test flight, they continued to support the two cosmonauts on board Mir. The Mir drawing above shows the complex in its current configuration with the new Progress 30 tanker docked to the back (far right). The Soyuz TM-2 transport remains docked to the forward hub of the station. Cosmonauts Col. Yuri Romanenko and Alexander Laveikin, who were launched Feb. 6, are starting their 17th week in space. The U. S. will be unable to undertake manned space station operations until at least 1994-95—20 years after abandoning Skylab operations.

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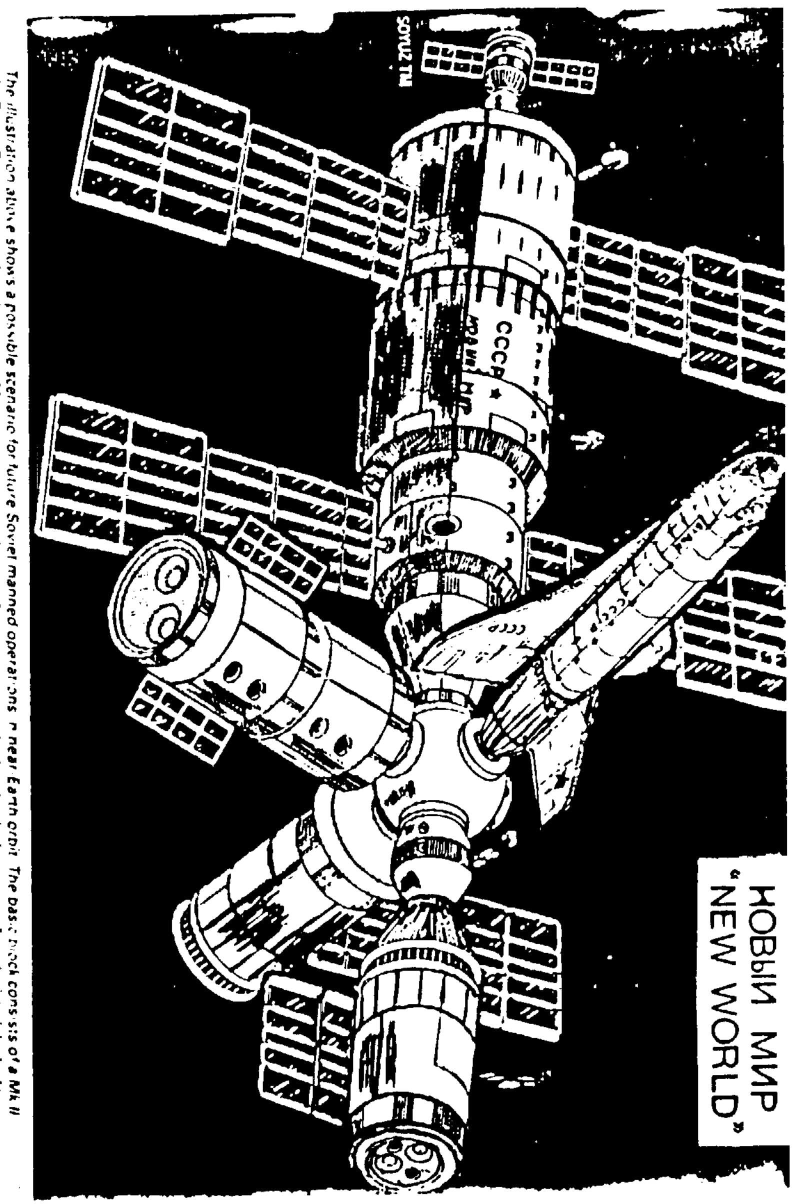

The illustration above shows a possible scenario for future Soviet manned operations in near Earth orbit. The basic block consists of a Mk II Mir Space Station, larger than the current Mir, with various modules and extensions attached to the docking ports. Also depicted docked to a lateral port is a Soviet Shuttle craft. In his paper "The Soviet Space Shuttle Programme" Mr. Tony Lawton said the Shuttle had undergone six firings to date and was "almost ready to go". He surmised that the first flight would be entirely automatic.

Spaceflight Magazine

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6.11.6 CHINESE

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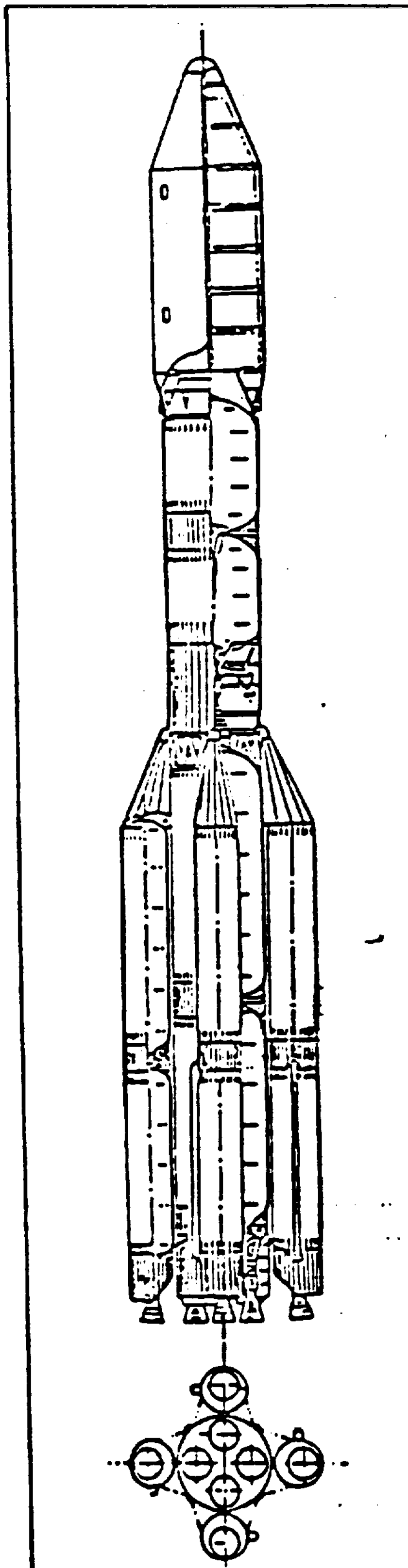
6.11.6 Chinese



By Craig Covault

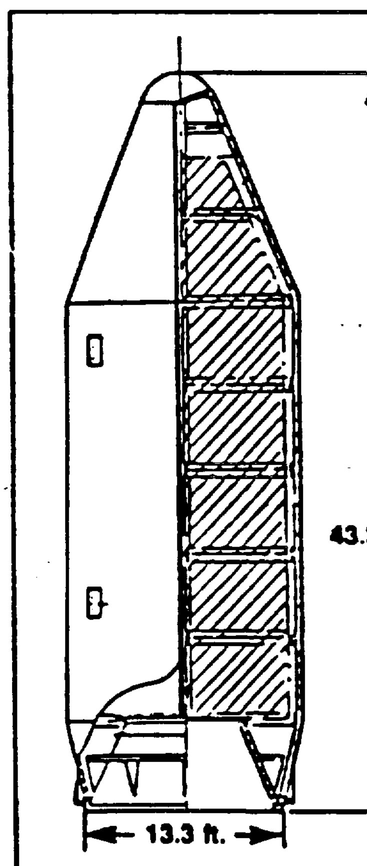
Washington—The People's Republic of China is beginning a new global campaign to market commercial launch services on its Long March boosters and has begun development of a heavy rocket to spearhead this effort into the 1990s.

China also plans to intensify efforts to buy U.S. and European space hardware as a means of increasing Chinese aerospace technology. The director of China's Great Wall Industry Corp., U Keli, told AVIATION WEEK & SPACE TECHNOLOGY that China has approved development of a new heavy space booster designed to utilize U.S. upper stages. The Chinese are also uprating their existing oxygen/hydrogen third stage to place atop the vehicle.

The new CZ2-4L booster, set for first flight in 1989, will have a liftoff thrust and weight comparable to the U.S. Saturn 1B and a 4,000-5,400-lb. geosynchronous transfer orbit payload comparable to the European Ariane 3/4 vehicles.

The new Chinese booster will be able to place 20,000-lb. payloads in low Earth orbit, a capability somewhat less than a USAF Titan 34D. It is being developed for Chinese military and scientific space needs but also complements China's commercial space market initiative.

Construction of a new launch pad for the 154-ft. booster will begin this fall at the Xichang launch site in southwest China.



Chinese CZ2-4L heavy booster will have a liftoff thrust and weight comparable to the U.S. Saturn 1B rocket and a geosynchronous transfer orbit payload capability comparable to the European Ariane 3/4. First flight is set for 1989 carrying a Chinese satellite, and commercial satellites can use the vehicle starting in 1990. Diagram at left shows the vehicle's four large side-mounted liquid boosters attached to a stretched Long March 2 core. The core will have an additional four engines. The vehicle will generate 1.24 million lb. of liftoff thrust. The side-mounted boosters do not separate but remain connected during first stage flight. Launch shroud (right) for the CZ2-4L will be 43.3 ft. long and 13.3 ft. wide. The booster is keyed toward launching the Hughes HS 393 spacecraft or two smaller spacecraft at a time.

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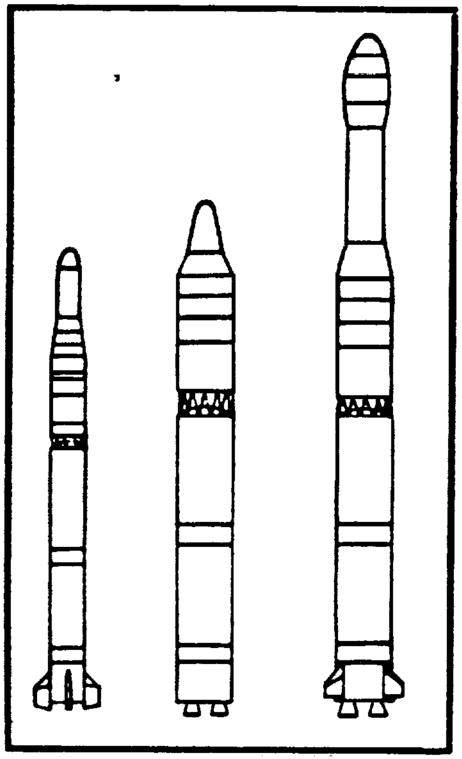


The family of Long March launch vehicles. Left: CZ-1. Centre: CZ-2. Right: CZ-3.

At the IAF Congress in 1986, details of more CZ-2 variants were announced [13], four in total. All the missions seem to be scaled for a launch from Xi Chang from where the CZ-2 can place 3.9 tonnes into a 28.5 deg, 200 km circular orbit. This vehicle with a stretched second stage could be used to carry a Hughes HS-376 communication satellite into a low parking orbit, with a PAM-D stage being carried for the manoeuvres to geosynchronous orbit.

The CZ-2 could also be used with a Hughes HS-399 communications satellite: in this version, the satellite with a mass of up to 1710 kg would be placed into a geosynchronous transfer orbit by the two stage CZ-2 and then its own apogee motor would perform the geosynchronous orbital injection.

A further CZ-2 variant could place a Molniya satellite into its drift orbit of about 400-40000 km, although the orbital inclination of the Soviet system (62.8 deg) probably could not be matched.

The most ambitious new CZ-2 variant would give the Chinese a major launch vehicle. A much stretched second stage would be carried, but the first stage would be augmented b[y] either four or eight strap-on booster[s]. In the four strap-on booster versio[n] nine tonnes could be placed in orbi[t] while the eight strap-on version coul[d] orbit 13 tonnes. It is possible that thi[s] variant is the CZ-4 which the Chines[e] have recently mentioned.

Another source described the CZ-[4] as being capable of placing 2040 k[g] into geosynchronous transfer orbit[:] this would use eight YF-2 engines clustered in the first stage (the existing firs[t] stage with four strap-ons, each havin[g] a single YF-2 ?) with the possible pro[-]curement of a new upper stage fro[m] the United States [14].

Using the CZ-4, a new geosynchron[-]ous payload launcher is being planne[d]. Designated CZ-4L, this is described a[s] an up-rated CZ-3 with four strap-on[s] [15]. The current third stage would b[e] replaced by a new cyrogenic stage, an[d] this combination would place 5.3 ton[-]nes into geosynchronous transfe[r] orbit, compared with 1.4 tonnes for th[e] existing CZ-3. The first flight of the CZ[-]4L is planned for 1991.

Table 3. Details of the CZ-3 Booster.

	Stage 1	Stage 2	Stage 3
Engine Designation	YF-2 (4)	YF-2 (1)	YF-73 (1)
Thrust, tonnes	280	70	5
Specific Impulse, sec	264	264	425
Burn Time, sec	132	129	451+291
Stage dry mass, tonnes	10	3.5	2.3
Propellant load, tonnes	140	34.2	8.7
Stage length, metres	20.22	7.51	7.48
Stage diameter, metres	3.35	3.35	2.25
Fuel	Nitrogen Tetroxide		L Hydrogen
Oxydiser	UDMH		L Oxygen

NOTES

These details are either given in the Long March 3 User's Manual or derived from the data contained therein. The total length of the booster is 44.68 metres. The payload shroud is 7.27 metres long (including the adapter to the third stage) and has a maximum diameter of 3.0 metres. The numbers in parentheses are the number of engines used in that stage. The thrust values are those for the total stage rather than for the engine itself. The third stage is re-started in flight, and initial burn lasts for 451 seconds for the basic orbital injection and then after coasting for 157 seconds it re-ignites for the manoeuvre to geosynchronous transfer orbit.

 Av Wk 7/27/87

Chinese Facility Combines Capabilities To Produce Long March Boosters, ICBMs

By Craig Covault

Wan Yuan—The People's Republic of China has built an aerospace industrial complex employing 23,000 people here to develop and assemble virtually all hardware associated with China's space boosters and heavy intercontinental ballistic missiles

McDonnell Douglas Corp. is about to begin formal discussions with the Chinese on mating the payload assist module (PAM) upper stage to Long March boosters made here in order to form a Chinese launch vehicle that would use a U. S. third stage.

This AVIATION WEEK & SPACE TECHNOLOGY editor recently toured the plant and was shown two Long March 2 vehicles in final checkout before being shipped to the Jiuquan launch site in the Gobi Desert. One of the vehicles is set to launch a Chinese military reconnaissance/Earth resources satellite in August.

The facility is known by two names, the Capital Machinery Co. and the Wan Yuan Industry Corp. My visit to the site was with a group of Chinese, Japanese and U. S. space officials attending the first Pacific Basin space conference sponsored by the American Astronautical Society and its Chinese and Japanese counterparts (AW&ST June 15, p. 66).

The industrial complex is based in the small town of Wan Yuan about 30 mi. south of Beijing. During the visit, a continual stream of horse-drawn carts passed the facility's security wall next to small peasant cottages with chickens running in the street. The complex is guarded by People's Liberation Army sentries armed with AK-47 automatic weapons.

Stage Construction

The first and second stages for the Long March 2 and the oxygen/hydrogen third stage for the Long March 3 are built in this complex. The first and second stages of the Long March 3 are built in Shanghai, but could be built here just as easily since they closely duplicate the Long March 2 configuration.

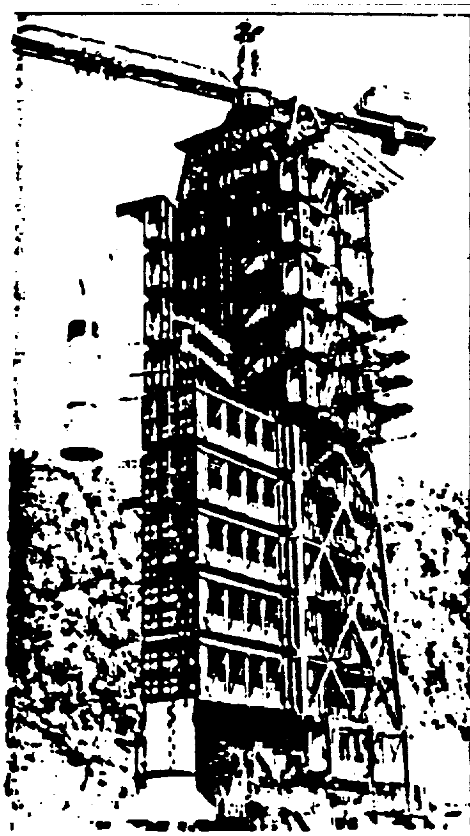
Facility Workforce

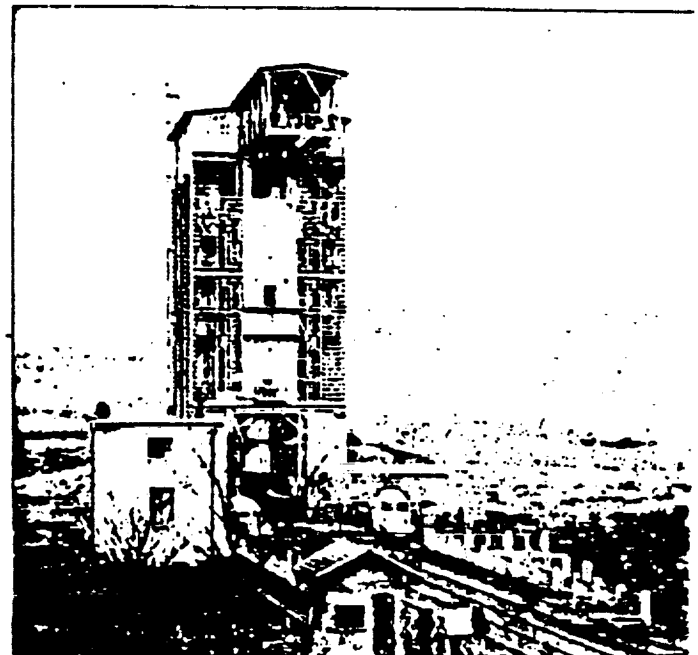
The workforce at the site is made up of 3,000 senior engineers, 5,000 middle- and junior-level engineers, and more than 10,000 skilled workers. The remainder of the labor force is involved in facility upkeep.

U. S. and Japanese space officials were impressed that the Chinese had assembled at one location the multidisciplinary research, development, manufacturing and test capability needed to build virtually all of the components used in their launch vehicles and ballistic missiles.

This approach is used partly to conform with Communist doctrine, which emphasizes centralized control, and partly because it is the only way China can manage such developments effectively given the country's limited subcontractor base.

Development of the oxygen/hydrogen-powered Long March 3 upper stage here provides an example of the results the Chinese have achieved with this intensive manpower approach.





Oxygen/hydrogen-powered third stage for the Long March 3 booster (left) is hoisted up the launch tower at the Xichang launch site in southwest China. The third stage is built by the Wan Yuan Industry Corp. Rocket engine test stand (above) southwest of Beijing is prepared for a firing test. This particular stand is one of several at the site used to test the oxygen/hydrogen engine system and smaller Chinese rocket engines.

The initial space test several years ago of the new third stage ended in a partial failure when its engines shut down prematurely during the second of two planned firings.

The factory diagnosed the problem as bubbles in a propellant line. The Chinese developed and tested new components, conducted four ground static firings, then launched the new hardware on an operational flight carrying China's first geosynchronous satellite—all within 70 days of the failure.

The facility here appeared to total over 100 acres, with six large factory complexes in the compound.

The plant also includes at least three other work centers and about eight research institutes, most located on this site but a few, such as an engine test center, located away from the main facility.

The factory complex is divided into four departments, covering management, systems engineering, production assurance and launch services.

Six separate factories within the complex are devoted to assembly of entire launch vehicles, as well as connectors, servomachinery, control system devices such as inertial gyros, telemetry systems and vehicle electrical systems.

The eight research institutes cover telemetry, materials, structural testing, ground support needs, antennas, flight control devices, rocket engine control systems and rocket propulsion.

A computer center also is part of the complex and computer graphics-aided design work is an integral part of the operations.

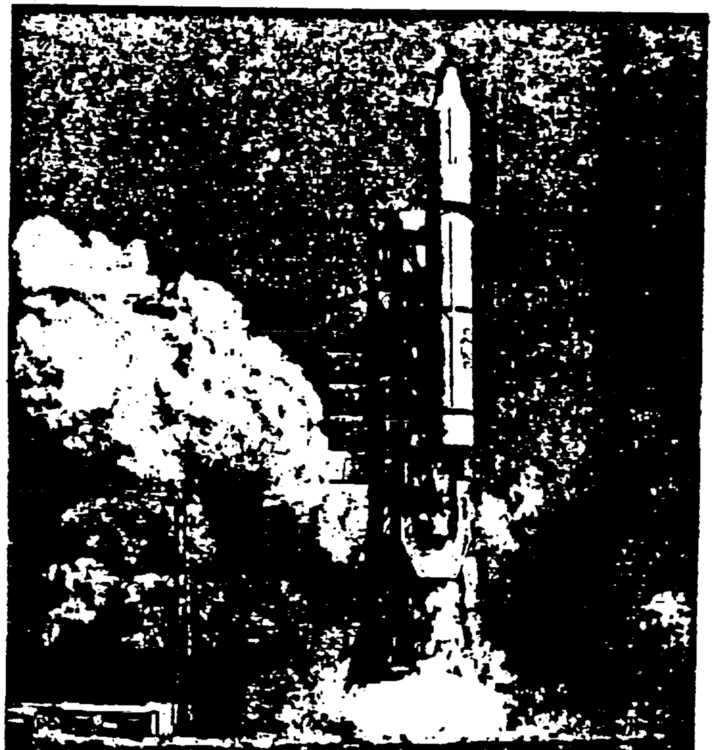
In addition to the basic Long March 2 and 3 boosters, the plant is working on multiple satellite deployment canisters. By using a three-tier payload cradle, four small satellites can be deployed from a single vehicle, reducing launch costs for the individual spacecraft sponsors (AWAST Oct. 13, 1986, p. 20). The Chinese are marketing this capability internationally.

Swedish Mailsat

Engineers here also are working with the Swedish Space Corp. in preparation for the upcoming Mailsat mission, in which the Swedish satellite will be carried as a piggyback payload along with a much larger Chinese low-altitude spacecraft.

A tour of the final checkout facility for Long March 2 boosters provided insight into Chinese clean-room and security operations.

The group passed numerous long, sin-



Chinese CZ-2C booster carrying a low Earth orbit satellite is launched from the Jiuquan site in north central China. This Long March 2 is built at the Wan Yuan Industry Corp., which also builds Chinese ballistic missiles.

gle-story, brick buildings on its way to the checkout facility in the center of the complex. Inside those buildings Chinese technicans could be seen working on various sheet-metal sections such as propellant tank domes.

The checkout facility was a 200-ft.-long, four-story brick hangar. Once inside we were asked to don slippers to prevent tracking dust. The clean-room procedures were not rigid, however. Support vehicles had been driven straight into the facility from the outside. Our group was not asked to don clean-room gowns, although other visitors who went in later were asked to wear them. Some of the Chinese in the facility wore clean-room garments, but others did not.

Two Long March 2 flight vehicles sat on rail transports in the checkout hall. Both vehicles were broken down into their first and second stages. An engineering mockup of the oxygen/hydrogen third stage also was in the facility for training.

One of the CZ-2s had just been completed and was awaiting shipment to the launch site. Deputy Manager Yang Jingshi provided a basic description of each vehicle's status during a walk-around of the rockets.

The Chinese displayed some sensitivity to security. Members of the group, including this editor, were taking notes of the briefing as we walked. Several times during this session, however, a different Chinese official would enter our midst and yank our hands away from our note pads.

Everyone kept taking notes and the security official finally gave up, faced with the persistence of the U.S./Japanese space delegation and the indifference of Yang to the perceived security breach.

Engine Thrust

Yang said the four first-stage engines and single second-stage powerplant each could produce 85 tons of thrust, but the Chinese operate the engines at only 71 tons to provide a large safety margin.

The first-stage engines were covered with large thermal blankets. Yang said that although the oxygen/hydrogen engines are built in the plant, the vehicle's first- and second-stage powerplants are built and tested in central China.

Examination of the oxygen/hydrogen stage showed that it had four small engine bells, indicating each chamber is a relatively low-thrust powerplant.

Yang said the facility is entering advanced development of the liquid-fueled strap-on boosters for the new Long March 2-4L. Each of its four strap-on boosters will carry a single engine identical to the powerplants already in the vehicle. The facility also is working to build the 4-meter (13-ft.) fairing that will be used on the 2-4L.

The plant operates large stands for vibration and thermal testing and has a large anechoic chamber for antenna development.

Scenes of the plant in the movie presentation showed as many as four Long March 2/DF-5 vehicles in simultaneous checkout here. Other views in the film included avionics assembly benches that stretched about 100 ft. and a similar area for checkout of rocket engine turbopumps, with about 10 pumps in view.

The Chinese said they use fusion welding, plasma arc welding and laser welding at the facility.

Most of the test and assembly areas appeared comparable to those in the West. Several of the areas had clean-room procedures in effect. ☐

Aviation Week & Space Techn.
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6.13 ACRONYM LISTING

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6.13 ACRONYMS and ABBREVIATIONS

$B	Dollars-billions
$M	Dollars-millions
AFD	Aft Flight Deck
AFSATCOM	Air Force Satellite Communications
AFSCF	Air Force Satellite Control Facility
AFSCN	Air Force Satellite Control Network
AFSCF/STC	Air Force Satellite Control Facility/Space Test Ctr.
AGCS	Automatic Ground Control System
AH	Ampere-Hour
AI	Artificial Intelligence
Al	Aluminum
Al-Li	Aluminum-Lithium
AOA	Abort Once Around
APU	Auxiliary Power Unit
ASE	Airborne Support Equipment
ASSY	Assembly
ATE	Automatic Test Equipment; Air Traffic Control
ATKB	Automation Technology Knowledge Base
ATO	Abort to Orbit
ATPG	Automatic Test Program Generation
A50	Aerozine 50 (50% Hydrazine and 50% UMDH)
BIT	Built-In-Test
BITE	Built-In-Test-Equipment
BSTR	Booster
C	Celsius; Carbon
C2K	Circa 2000
C_3H_8	Propane
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAI	Computer Aided Instruction
CALS	Computer Aided Logistics System
CAM	Computer Aided Manufacturing
CDDT	Countdown Demonstration Test
CDF	Confined Detonating Fuse
CECO	Center Engine Cutoff
CELV	Complimentary Expendable Launch Vehicle (now Titan IV)
CG	Center of Gravity
CH_4	Methane
CIM	Computer Integrated Manufacturing
CITE	Cargo Integration Test Equipment
CIU	Computer Interface Unit
CM	Command Module
C/O	Checkout
COMM	Communications
COMM SAT	Communication satellite
CPU	Central Processing Unit
CPV	Combined Pressure Vessel
CR	Control Room
Cryo	Cryogenic
CSOC	Consolidated Space Opertions Center
CT	Crawler Transporter
CTS	Common Tank Set
CV	Cargo Vehicle
CVD	Chemical Vapor Deposition
DA	Data Acquisition
D/A	Digital/Analog

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6.13 ACRONYMS and ABBREVIATIONS (Continued)

DAS	Data Acquisition System
DB	Data Base
DBMS	Data Base Management System
DBS	Direct Broadcast Satellite
DBT	Design Build Team
dc	Unit Current
DCA	Defense Communications Agency
DDT&E	Design, Development, Test and Evaluation
DFT	Design For Testability DMS Data Management System
DOD,DoD	Department of Defense
DOMSAT	Domestic communication satellite
DPS	Data Processing System
DSCS	Defense Satellite Communication System
DSN	Deep Space Network DSP Defense Support Program
DTC	Design to Cost DR Discrepancy Report
ECLSS	Environmental Control & Life Support System
ECS	Environmental Control System
EECOM	Electrical, Environmental, Communications
EIU	Engine Interface Unit
ELS	Eastern launch site
ELV	Expendable Launch Vehicle
EMC	Electro magnetic compatibility
EMU	Extra-vehicular Mobile Unit
EPD&C	Electrical Power Distribution and Control
EPS	Electrical Power Subsystem
ES	Expert System
ESS	Energy Storage System
E/T	External Tank
ETR	Eastern Test Range
EVA	Extra Vehicular Activity
FAA	Federal Aviation Administration
FCE	Flight Crew Equipment
FCM	Fuel Cell Module
FDO	Flight Dynamics Officer
FMS	Flight Management System
FRCS	Forward reaction control system
FSS	Flight Systems Simulator
FWC	Filament Wound Case
FY	Fiscal Year
GB	Ground based
GD	General Dynamics
GEO	Geosynchronous; Geosynch. Orbit
GFS	Government Furnished Support
GH2, GH_2	Gaseous Hydrogen
GLOW	Gross Liftoff Weight
GN&C,(G&C)	Guidance Navigation and Control
GN_2	Gaseous Nitrogen
GO	Ground Operations
GO2,GO_2	Gaseous Oxygen
GPM	Gallons Per Minute
GPS	Global Positioning Satellite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSTDN(STDN)	Ground Station Tracking and Data Network
HC	Hydrocarbon
He	Helium

HEO	High Earth Orbit
HIF	Horizontal Integration Facility
HLLV	Heavy Lift Launch Vehicle
HPFTP	High Pressure Fuel Turbo Pump
HTO	Horizontal Take Off
H/W	Hardware
H_2	Hydrogen
HYD	Hydraulic(s)
IC	Integrated Circuit
IDSS	Integrated Design Support System
I/F	Interface
IMIS	Integrated Maintenance Information System
IFA	In-flight Anomaly
ILS	Integrated Logistics System
IMU	Inertial Measurement Unit
INCO	Instrumentation and Communications Officer
INEL	Idaho National Engineering Laboratory
INS,INST	Instrumentation
INT	Integration
IOC	Initial Operational Capability
I/O	Input/Output
IPR	Interim Problem Report
IPV	Individual Pressure Vessel
IR	Infrared
IR&D	Independent Research and Development
IRR	Internal Rate of Return
Isp	Specific Impulse
IU	Interface Unit
IUS	Inertial Upper Stage
JSC	Johnson Space Center
K	Thousand
KEW	Kinetic Energy Weapon
KSC	Kennedy Space Center
KW	Kilowatt
LAN	Local Area Network
LBS	pounds
LCA	Launch Control Amplifier
LCC	Life Cycle Cost
LCE	Low Cost Expendable
LCEP	Low Cost Expendable Propulsion
LC-Titan	Large Core Titan
LDC	Large Diameter Core
LEM	Lunan Excursion Module
LES	Launch Escape System
LEO	Low earth orbit
LH	Left Hand
LH2,LH_2	Liquid Hydrogen
Li-$SOCl_2$	Lithium Sulphur Oxygen Chlorine
Li	Lithium
LN_2	Liquid Nitrogen
LO2,LO_2	Liquid Oxygen
LPS	Launch Processing System
LRBs	Liquid Rocket Boosters
LRE	Liquid Rocket Engine
LRU	Line Replaceable Unit

LSC	Linear Shaped Charge
LV	Launch Vehicle
L&L	Launch and Landing
M	Million
MC	Mission Control
MCC	Main Combustion Chamber
MCR	Modification Change Request
MCS	Mission Control System
MCT	Mission Control Teams
MDAC	McDonnell Douglas Astronautics Company
MDM	Multiplex/DeMultiplex
ME	Main Engine; Maintenance Expert
MELV	Medium Expendable Launch Vehicle
MEO	Medium earth orbit
MFRCV	Manned Fully Reusable Cargo Vehicle(s) (STS II)
MFRGB	Manned Fully Reusable Ground Based-OTV
MFRSB	Manned Fully Reusable Space Based-OTV
MILSTAR	Military Transmission and Relay Satellite
MLP	Mobile Launcher Platform
MMC	Martin Marietta Company
MMMA	Martin Marietta Michoud Aerospace
MMU	Manned Maneuvering Unit
MPM	Manipulator Positioning Mechanism
MPRCV	Manned Partially Reusable Cargo Vehicle
MPS	Main Propulsion System
MPSR	Multipurpose Support Room
MPST	Multipurpose Support Team
MSBLS	Microwave Scanning Beam Landing System
MSFC	Marshall Space Flight Center
MS/NAS	Machine Screw/National Aircraft Standard
MTBF	Mean-Time Between Failure
NaS	Sodium Sulphur
NAS	National Airspace System
NA-S	National Aircraft Standard
NASA	National Aeronautics and Space Administration
NASA/RECON	Remote console (NASA information retrieval system)
NCCS	Network Communication and Control Stations
NCS	Network Control Stations
NDE	non-destructive evaluation
NDT	Non-Destructive Test
Ni-Cd	Nickel-Cadmium
NiCad	Nickel Cadmium
NIH	Not Invented Here
Ni-H_2	Nickel-Hydrogen
NiTi	Nickel-Titanium
Nitinol	Nickel-Titanium-Naval Ordnance Laboratory
NLG	Nose Landing Gear
NORAD	North American Air Defense
NSI	NASA Standard Initiator
N_2H_4	Hydrazine Monopropellant
N_2O_4	Nitrogen Tetroxide
OAA	Orbiter Access Arm
OBECO	Outboard Engine Cutoff
OMI	Operations and Maintenance Instruction
OMP	Operation Maintenance Plan

OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OMV	Orbital Maneuvering Vehicle
OPC	Operations Planning Center
OPF	Orbiter Processing Facility
OPS	Operations
ORB	Orbiter
ORU	Orbiter Replacement Unit; Orbital Repaired Unit
OTV	Oribital Transfer Vehicle
OV	Orbiter Vehicle
P/A	Propulsion/Avionics module
PAM	Payload Assist Module; Payload Applications Module
PAREC	P/A Recovery Area
PC	Printed Circuit
PCBS	Printed Circuit Boards
PCP	Power Control Panel
PCR	Payload Changeout Room
PDI	Payload Data Interleaver
PDR	Preliminary Design Review
PFLB	Pressure Fed Liquid Booster
PGHM	Payload Ground Handling Mechanism
PGOC	Payload Ground Operations Contractor (MDAC)
PIC	Pyro Initiator Controller
PIDB	Preliminary Issues Database
PL, P/L	Payload
PLB	Payload Bay
PLF	Payload Fairing or Payload Facility
POCC	Payload Operations Control Center
POI	Product of Inertia
PR	Problem Report
PRCBD	Program Review Control Board Directive
PRSD	Power Reactant Storage and Distribution
PSA	Payload Support Avionics
PSI	Pounds Per Square Inch
PSP	Processing Support Plan
PV	Present Value
PV&D	Purge, Vent and Drain
P/A	Propulsion/Avionics
P/FRCV	Partially/Fully Reusable Cargo Vehicle
QA	Quality Assurance
QC	Quality Control
QD	Quick Disconnect
RADC	Rome Air Development Center
RAMCAD	Reliability and Maintainability through Computer Aided Design
RCC	Reinforced Carbon Carbon
RCS	Reaction Control System
R&D	Research and Development
RECON	Remote Console (NASA information retrieval system)
RF	Radio Frequency
RFCS	Regenerative Fuel Cell System
RFP	Request for Proposal
RH	Right Hand
RIC	Rockwell International Corporation
RJDA	Reaction Jet Drawer
RMS	Remote Manipulator System
R&PM	Research and Program Management

RPSF	Rocket Propellant Servicing Facility
RP-1	Rocket propellant-JP-X based
R/R,R&R	Repair/Replace
RSI	Reusable Surface Insulation
RTOMI	Repetitive Task Operations and Maintenance Instruction
RTS	Remote Tracking System
RTV	Room Temperature Vulcanizing
R&T	Research and Technology
RU	Remote Unit
S	Sulphur
SAFT	Semi-Automatic Flight line Tester
SAT	Satellite
S&A	Safe and Arm
SB	Space Based
SBS	Space Based System
SBSS	Space Based Space Surveillance (System)
S/C	Spacecraft
SCAPE	Self-Contained Atmospheric Protective Ensemble
SDI	Space Defense Initiative
SDIO	Space Defense Initiative Office/Organization
SDV	Shuttle Derived Vehicle
SiC	Silicon Carbon
SIP	Standard Interface Panel; Strain Isolation Pad
SIT	System Integrated Test
SLSOC	Simplified Launch System Operational Criteria
SM	Support Module
SMA	Shape-memory alloy
SMCH	Standard Mission Cable Harness
SME	Shape Memory Effect
SOA	State-of-Art
SOC	Satellite Operations Center
SOPC	Shuttle Operations Planning Center
SOW	Statement of Work
SPACECOM	Space Command
SPADOC	Space Defense Operations Center
SPC	Shuttle Processing Contractor (Lockheed)
SPIDPO	Shuttle Payload Integration and Development Program Office (JSC)
SPDMS	Shuttle Processing Data Management System
SPI	Standard Practice Instructions
SRB, SRBs	Solid Rocket Booster(s)
SRM, SRMs	Solid Rocket Motor(s)
SRSS	Shuttle Range Safety System
SS	Space Station
SSME	Space Shuttle Main Engine(s)
SSMEC	Space Shuttle Main Engine Controller
SSSF	SRB Segment Storage Facility
SSTO	Single Stage to Orbit
ST	Space Telescope
STA,STAS	Space Transportation Architecture (Study)
STC	Satellite Test Center
STE	Systems Test and Evaluation or Special Test Equipment
STS	Space Transportation System
STS II	Space Transportation System II
SV	Space Vehicle
S\W,(SW)	Software
T-III	Titan III
TACAN	Tactical Navigation
TARS	Turnaround and Reconfiguration Simulation
TAV	Transatmospheric Vehicle

6.13 ACRONYMS and ABBREVIATIONS (Continued)

TBD	To be Determined/Defined
TDAS	Tracking and Data Acquisition Satellite
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TE	Test Equipment
TIS	Technology Identification Sheet
TM	Telemetry
TP	Test Point; Test Plan
T-0	Liftoff Time
TOs	Transfer Orbit Stage
TPS	Thermal Protection System; Test Preparation Test
TRAJ	Trajectory
TS	Transportation System
T/S	Test Setup
TSM	Tail Service Mast
T&CN	Telemetry & communication network
TTL	Transistor/Transistor Logic
TVC	Thrust Vector Control
UART	Universal Asynchonous Transistor
UDS	Universal Documentation System
UEXCV	Unmanned Expendable Cargo Vehicle
UFRCV	Unmanned Fully Reusable Cargo Vehicle
UFRGB	Unmanned Fully Reusable Ground Based-OTV
UFRSB	Unmanned Fully Reusable Space Based-OTV
UHF	Ultra High Frequency
ULCE	Unified Life Cycle Engineering
ULV	Unmanned Launch Vehicle
UMDH	Unsymmetrical Dimethylhydrazine
UPRCV	Unmanned Partially Reusable Cargo Vehicle(s)
UPRCV(R)	Unmanned Partially Reusable Cargo Vehicle with return
UPXCV	Unmanned Partially Expendable Cargo Vehicle
UMB	Umbilical
VAB	Vehicle Assembly Building
VAFB	Vandenberg Air Force Base
VC1	Visual Clean 1 (standard)
VC1A	Visual Clean 1A (sensitive)
VC2	Visual Clean 2 (highly sensitive)
VHF	Very High Frequency
VHSIC	Very High Speed Integrated Circuit
VIB	Vertical Integration Building
VIF	Vertical Integration Facility
VLSI	Very Large Scale Integration
VPF	Vertical Processing Facility
WAD	Work Authorization Document
WBS	Work Breakdown Structure
WEM	Water Electrolysis Module
WCCS	Window Cavity Conditioning System
WSMC	Western Space and Missile Center
WCS	Waste Conditioning System
WSB	Water Spray Boiler
WTR	Western Test Range
XTKB	Expanded Technology Knowledge Base

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